SWINE FEEDING AND NUTRITION

A Series on
ANIMAL FEEDING AND NUTRITION

HANS R. ROSENBERG, *Consulting Editor*
Newark, Delaware

Volume I
SWINE FEEDING AND NUTRITION
By Tony J. Cunha

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To Mr. & Mrs. FRED T. ROSEBERRY
Los Banos and Santa Cruz
California

and to my wife and family
this book is dedicated
in appreciation

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INTRODUCTION TO THE SERIES

The series of books on Animal Feeding and Nutrition, of which this is the first volume, is being published as a service to those who seek knowledge in this field. Accurate, concise, and authoritative information in this area is difficult to obtain, partly because such vast quantities of material are being written on this subject and partly because it is a task requiring special skill and experience to correlate new scientific data with the body of established principles and practices.

Nutrition, in its various aspects, is of vast economic and national importance. How to feed adequately the world's population today and how to provide, in the future, the food for our own ever-increasing population is a problem of serious concern. Optimistic as we are that the solutions to these questions will be found in time, the personnel dedicated to the search for progress must be provided with the best possible facilities. These include improved methods for effective dissemination of information and the speedy preparation and publication of summaries in important areas. In the recent past, research in nutrition has been so productive that feeding practices have changed rapidly. That these changes have been of a major nature is the most surprising aspect of this situation. In all likelihood there will be more advances in the near future and we foresee a continuing need for summarizing these developments in up-to date books.

In the present series the publisher hopes to provide a new means of disseminating current information on all phases of animal feeding and nutrition, written by top authorities in the field. This first volume on swine feeding and nutrition will soon be

followed by books dealing with poultry and cattle. Other subjects may be added later.

To help introduce a new series of books is a privilege. It has been a joy to advise on this project and to be able to witness the appearance of the first volume. It is my pleasure to thank the author and publisher for their great efforts.

May 13, 1957 H. R. R.

AUTHOR'S PREFACE

The purpose of this book is to provide information helpful to those interested in swine feeding and nutrition. It is designed to be valuable to beginners in swine production, to established swine raisers, and to those who are concerned, directly or indirectly, with swine feeding or nutrition. This text will be particularly useful to feed manufacturers and dealers and others concerned with producing the many different nutrients, supplements, feeds, and other ingredients used in swine rations. It will also be of value to county agents, to veterinarians, and to students, and teachers of vocational agriculture. It is also designed to be useful for college students and teachers in courses on feeds and feeding, swine production, swine nutrition, and animal nutrition. The text contains basic information for students in these classes. Besides, it contains many key references for those interested in obtaining further information on a particular subject.

The first six chapters contain concise, up-to-date summaries on proteins, amino acids, minerals, vitamins, carbohydrates, fiber, fats, water, antibiotics, surfactants, arsenicals, enzymes, and hormones in swine feeding and nutrition. The requirements of the pig for all the various nutrients are discussed and compared to National Research Council recommendations. Deficiency symptoms for all nutrients are discussed and most nutritional deficiencies are illustrated with photographs. These chapters summarize the needs of the pig for various nutrients and give the reader a basis for determining what good, well-balanced rations should contain. The practical application of this basic information is discussed in each chapter.

The last three chapters deal with a concise summary on the relative value of feeds, and on feeding the breeding herd and pigs during the various stages of their life cycle. The advantages and disadvantages of early weaning are discussed. Prestarter, starter, grower, fattening, gestation, and lactation rations are discussed. Sample rations are given to be used as guides in making up rations. The use of silage and other high roughage feeds for swine feeding is discussed. These last three chapters on feeding make use of the basic nutrition information discussed in the first six chapters.

In preparing this text the author has had the benefit of suggestions and review of certain chapters by the following specialists and competent persons in the field of swine nutrition: W. M. Beeson (Purdue), G. Bohstedt (Wisconsin), D. V. Catron (Iowa State), G. E. Combs (Florida), L. E. Hansen (Minnesota), S. W. Terrill (Illinois), R. F. Sewell (Georgia), and H. D. Wallace (Florida). The author wishes to express his sincere appreciation to them and to William G. Mitchell, Assistant Editor, University of Florida, who performed an excellent job in editing the entire manuscript. The author also wishes to express his thanks to all those who supplied photographs and other material used in the text. He also welcomes any suggestions for improving the text in the next revision.

T. J. Cunha

Gainesville, Florida
June, 1957

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CHAPTER I

Feed Nutrients for the Pig

1.0 INTRODUCTION

Feed represents about 80 per cent of the cost of producing hogs. Thus, successful swine production requires a carefully planned and efficient feeding program. Rations that would serve a few years ago are not adequate now (Fig. 1). Swine production is becoming more intensified and specialized.

Fig. 1 This shows the progress which has been made since 1910 in the nutrition of the pig. New developments in swine feeding should make it possible to obtain even more pork with less feed in the next 20-year period. (Courtesy L. E. Hanson, Minnesota Agricultural Experiment Station.)

Through proper breeding and selection, rapidly growing strains of swine have been developed. Many swine producers now plan to market their hogs at close to five months of age instead of the seven to eight months that was accepted practice a few years ago. Moreover, they are selecting and breeding for larger litters and are breeding their sows to farrow twice a

year. In some cases, where producers practice early weaning a sow produces about five litters in two years. Gilts are being bred to farrow their first litters at an earlier age than in the past, also.

1.1 NEED WELL BALANCED RATIONS

To meet this intensified and stepped-up hog production program, properly balanced, high-quality rations must be fed. This means that nutritional needs of the pig for carbohydrates, fats, proteins, minerals, and vitamins must be met fully for profitable and efficient production. No matter how careful one is in his breeding, management, and disease control program (and these are very important), one cannot make a profit unless the hogs are fed properly. For these reasons, those concerned with swine feeding need to know the nutrient requirements of the pig, the characteristics of a good ration, and the nutritive value of the feeds used in swine rations. They also need to learn how to put all this information together into a well-balanced and economical feeding program. Finally, they need to recognize the critical periods in swine feeding and learn to meet their demands.

1.2 PREVENTING SMALL PIG LOSSES

Extensive surveys show that between 30 and 40 per cent of all pigs farrowed die before they reach market (Fig. 2). This results in a tremendous loss to the swine producers each year. Not all swine losses can be traced to faulty nutrition, but nutritional deficiencies account for a good part of them. Certainly, we can visualize what business havoc would occur to a feed or car manufacturer if he lost 40 per cent of his product before it was sold. Thus, the problem of small pig deaths is one which needs considerable study. Such study is needed to eliminate as much as possible the handicap of "small pig losses" which the swine producer has to contend with year after year. Producers can eliminate these losses only by practicing a better job of feeding.

The problem of adequate nutrition for the sow and the very young pig is a challenging one It is not always given needed

Fig 2 This is a weak litter of pigs owing to a lack of vitamins in the ration Most, if not all, pigs born in this weakened condition die Proper feeding will prevent this heavy toll of small pig losses (Courtesy T J Cunha and M E Ensminger, Washington Agricultural Experiment Station)

attention on the average farm The following figures show how much feed is lost by the death of young pigs (3)

Age at death	Amount of feed lost pounds per pig
Birth	140
10 weeks	260
18 weeks	360
26 weeks	602
34 weeks	990

By using current feed prices, one can determine readily how much the loss of each pig means in dollars and cents These figures will also show why it is so important to do a good job of feeding in order to eliminate as many as possible of these small pig losses

1.3 WHAT MAKES A GOOD RATION

In balancing swine rations, most nutritionists think in terms of nutrients and not just feeds, as used to be the case. A "nutrient" is any food constituent which aids in the support of animal life. Today, these known nutrients consist of 10 essential amino acids, 17 vitamins, 13 or more essential mineral elements, essential fatty acids, carbohydrates, and unidentified factors which need to be taken into consideration in compounding a ration.

Fig. 3. Preserved pig embryos at 30, 60, 80 90, and 106 days of development during gestation. Note that pig is still very small at 30 days. (Courtesy Dr. R. M. Bethke, Ralston Purina Co., St. Louis, Missouri.)

These nutrients need to be furnished in such proportion, level, and form as will nourish properly the age pig to which they are fed. Not only is the amount of a nutrient important, but it needs to be fed in the correct proportion with other nutrients for maximum utilization. This amount and proportion will usually vary with the age of the pig and the stage of its life cycle. For example, young, growing pigs have different requirements from those of older animals. The nutritional requirements of the sow are different from those of the growing pig. Requirements during lactation are greater than during gestation (Fig. 3).

A good ration also must be palatable Unless the pig consumes the ration readily, it is not a good one—regardless of how well balanced it may be or what the chemical analyses may indicate The pig is the final judge as to how palatable a feed is The fineness of grind will affect palatability The amount of mineral and high fiber feeds in the ration will also affect palatability Certain feeds and nutrients added to the ration will increase palatability and others will decrease it All this must be kept in mind in arriving at a combination of feeds and supplements to make a well-balanced ration This means that a knowledge of feeds and supplements is very necessary with regard to their overall effect on palatability or desirability of the ration for the pig

Well-balanced rations will usually contain a variety of feeds and supplements A variety of feeds tends to improve the balance of the ration and thus prevent certain nutritional deficiencies Besides, a variety of feeds will usually make the ration more palatable However, with our advancing knowledge of nutrition, it has become easier to supplement simple rations with the nutrients which they may lack It is very possible that in the not-too-distant future, as these nutrients become available in larger quantities and thus become lower in price, more of them will be used Thus, more simple rations, properly fortified, may be fed

A ration must be economical It takes skill and know-how to balance a ration properly and make it an economical one at the same time Thus, it is important to know the relative values of feeds, so that one may take advantage of price differences and changes The alert feeder or feed manufacturer will always be on the watch for price differences and changes which present an opportunity for increased profits Many times a good knowledge on this score will mean the difference between profit and loss

Toxic substances must be avoided in compounding rations This means that one needs a knowledge of injurious substances which feed ingredients may contain Fluorine in raw rock

phosphate, selenium in grains from selenium areas, gossypol in cottonseed meal, ergot in rye, scab in barley, and limonin in citrus seed meal are examples of some of these substances. Fluorine can be removed from raw rock phosphate to make it safe for swine feeding. Cottonseed meal is now being processed so that the gossypol is reduced to very low levels. This meal can be safely fed, with excellent results, as the sole protein supplement for swine. Ergot in rye will cause abortions and so should not be fed to pregnant sows.

Discussion on these toxic substances and other limitations of various feeds will be included in later chapters in this book. This short discussion will serve to illustrate the point that a feeding test is the final criterion of the value of a feed.

Many feeds will show promise from a chemical analysis standpoint. The analyses serve as a good guide in determining the value of a feed. But the final test will be how the pig performs when the feed is given to him in a well-balanced ration. A routine chemical analysis may not show that the feed contains a toxic substance; nor does it tell how palatable the feed may be. Many feeds will not give good results if used in high levels in the ration, but will give excellent results if included at a low level. This means that new feeds should be studied at various levels in the ration before one can obtain a good evaluation of them.

Some feeds may produce soft pork if fed long enough and at high enough levels. Soybeans, peanuts, chufas, hominy feed, rice bran, rice polish, sesame seed, sunflower seed, flaxseed, mast, buckwheat, garbage, and other feeds produce soft pork. Since pigs with soft pork are discounted heavily on the market, this problem requires serious consideration. When these feeds are used, they should be fed at low levels, and the pigs should be fed hardening feeds after they weigh 100 to 125 pounds. Thus, the effect of feeds on the quality of the carcass is another important aspect of ration formulation.

Feeds which are apt to become rancid must be guarded against. Rancid rations are low in palatability. Moreover, rancidity destroys certain nutrients in the intestinal tract. For example,

rancidity destroys certain vitamins. Proper transportation and storage of feeds will lessen this rancidity problem.

Feeds and supplements need to be adapted to the areas in which they will be used. In the corn belt, rations are built around corn. In the West, the Southwest, and other neighboring areas, swine rations include more barley, wheat, oats, and grain sorghum. In the Southeast, peanuts and corn are used to a great extent in swine feeding. In the Northeast and near large cities, garbage feeding operations abound. On many dairy farms, skim milk is still used in swine feeding, although less of it is being fed to swine and more is being used for human consumption. Thus, it is important that feed manufacturers make supplements which will balance the home-grown feeds available in the various areas of the country.

1.4 UNDERFEEDING AND OVERFEEDING

The first problem to be met from a nutritional standpoint is providing the pig enough to eat. This is still one of the biggest and most serious problems in swine feeding. If a pig does not get enough feed, it is apt to lack energy, as well as protein, minerals, and vitamins.

This is a very important point. Many swine producers will buy the most carefully balanced supplement or complete feed they can find; but they fail to feed enough of it to their pigs. As a result the animals become deficient in certain nutrients. This problem should be considered by feed manufacturers. They might suggest on the feed tag that a certain amount of the feed or supplement be fed daily to supply the nutrient requirements of pigs of various weights. Or the manufacturers might provide literature and education programs for their customers giving this information in more detail. No matter how the information is provided, it is very important that swine producers be impressed with the fact that a well-balanced feed will not do the job unless it is fed in adequate amounts.

Using unbalanced rations is also a form of underfeeding. Many swine producers still make this mistake. They are

reluctant to buy the necessary ingredients to balance their rations. But doing this is being penny-wise and pound-foolish. It is profitable to buy whatever nutrients, supplements, or feeds are necessary to provide the pig with its daily requirements of proteins, minerals, and vitamins. Rapid growth requires less feed per pound of weight increase than slow growth. This means that, in most cases, pigs should be fed for market in as short a period as possible. There are some exceptions to this where a ration having limited energy, but still supplying needed protein, minerals, and vitamins, may have a place. This is especially true where regulating the quantity of feed may control the degree of fatness of the animal. Breeding animals and prospective herd replacement animals are *usually* not fed in excess. Animals that are too fat will not reproduce as well as those kept in moderate condition.

1.5 REGULARITY AND CHANGES IN FEEDING

Regularity of feeding will repay the feeder. Animals respond to regularity, the same as human beings do, and it should be part of a good feeding program. Sudden changes in feed may throw an animal off-feed. Make any major changes in the ration gradually. Take several days to change from one important feed to another. Swine producers never notice much of the effect of abrupt changing from one feed to another. It occurs, however, and especially with very young pigs. Sometimes it is slight, but other times it may cause diarrhea and the animal may go off-feed for several days. Avoiding any such loss—if it can be avoided—is to the benefit of the feeder.

1.6 NUTRIENT REQUIREMENTS OF THE PIG

Information is not available on *all* the nutrients required by the pig. Tables I and II supply facts on the nutrients for which there is fairly good information available. Each one of these nutrients will be discussed more in detail in Chapters II, III, and IV, which deal with minerals, proteins, and vitamins.

The other nutrients, not included in Table I, will also be discussed in Chapters II, III, and IV

The suggested requirements given in Table I are based on experimental evidence and were worked out by the Committee on Nutrient Requirements of Swine of the National Research Council (1) The values in Table I represent an approximate—but not necessarily an exact—average of the experimental results Further discussion of each of these requirements will be given in Chapters II, III, and IV dealing with these nutrients

The recommended nutrient levels given in Tables I and II are to be used as a guide In most cases, they do not contain a margin of safety The recommended levels are slightly lower in some cases than levels shown to be needed by certain investigators This is discussed in detail for each nutrient in Chapters II, III, and IV Thus, feed manufacturers and swine feeders may find it desirable, in some cases, to increase the level of certain nutrients whenever transportation and storage conditions may cause some deterioration of that nutrient or when they feel that a higher level might be desirable for some other reason

1 6a Variation in Requirements by Animals

Most of the experimental work on the nutritive requirements of animals is based on the performance of a group of animals The average of the group is used to determine rate of gain and feed efficiency When deficiency symptoms are the criteria of nutrient adequacy, lack of the deficiency symptoms in a group of pigs is usually the basis for the investigators' conclusions In any group of animals, there may be some pigs that are borderline in the nutrient and thus show no deficiency symptoms They are deficient in the nutrient, nevertheless, and it may be resulting only in some decrease in rate of gain or feed efficiency Thus, although the nutrient may be adequate for a majority of the animals, it may be deficient for some animals who have a higher requirement or for some reason do not utilize it efficiently

One such example is a recent study at Michigan State (2) This showed that a level of 4 15 mg of pantothenic acid per

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TABLE I. Nutrient Requirements for Swine in Percentage or Amount per Pound of Total Ration[a]

	Description of pigs									
	Market stock						Breeding stock			
							Pregnant females and breeding boars		Lactating females	
							Young stock	Adults	Gilts	Adults
Live weight, lb.	25	50	100	150	200	250	300	500	350	450
Expected daily gain, lb.	0.8	1.2	1.6	1.8	1.8	1.8	0.75	0.5	—	—
Total digestible nutrients, lb.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Crude protein, %	18.0	16.0	14.0	13.0	12.0	12.0	15.0	14.0	15.0	14.0
Inorganic nutrients:										
Calcium, %	0.8	0.65	0.65	0.55	0.55	0.55	0.6	0.6	0.6	0.6
Phosphorus, %	0.6	0.45	0.45	0.33	0.33	0.33	0.4	0.4	0.4	0.4
Salt (NaCl) %	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamins:										
Carotene, mg.	0.75	0.75	0.75	1.0	1.0	1.0	2.5	2.5	2.5	2.5
Vitamin D, I.U.	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
Thiamine, mg.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Riboflavin, mg.	1.2	1.0	1.0	1.0	1.0	1.0	1.2	1.2	1.2	1.2
Niacin, mg.	8.0	6.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pantothenic acid, mg.	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Pyridoxine, mg.	0.6	0.6	—	—	—	—	—	—	—	—
Choline, mg.	400.0	—	—	—	—	—	—	—	—	—
Vitamin B_{12}, mcg.	7.0	5.0	5.0	—	—	—	—	—	—	—

[a] Source: National Research Council (1).

	Description of pigs									
	Market stock						Breeding stock			
							Pregnant females and breeding boars		Lactating females	
							Young stock	Adults	Gilts	Adults
Live weight, lb	25	50	100	150	200	250	300	500	350	450
Expected daily gain, lb	0 8	1 2	1 6	1 8	1 8	1 8	0 75	0 5	—	—
Total feed (air dry) lb	2 0	3 2	5 3	6 8	7 5	8 3	6 0	7 5	11 0	12 5
Total digestible nutrients (75% TDN) lb	1 6[b]	2 4	4 0	5 1	5 6	6 2	4 5	5 6	8 3	9 4
Crude protein, lb	0 36	0 51	0 74	0 88	0 90	1 00	0 90	1 05	1 65	1 75
Inorganic nutrients										
Calcium, grams	7 3	9 4	15 6	17 0	18 7	20 7	16 3	20 4	30 0	34 0
Phosphorus, grams	5 4	6 5	10 8	10 2	11 2	12 4	10 9	13 6	20 0	22 7
Salt (NaCl), grams	4 5	7 3	12 0	15 4	17 0	18 8	13 6	17 0	25 0	28 4
Vitamins										
Carotene, mg	0 5	1 0	2 0	3 0	4 0	5 0	15 0	18 7	27 5	31 2
Vitamin D, I U	180 0	288 0	477 0	612 0	675 0	747 0	540 0	675 0	990 0	1125 0
Thiamine, mg	1 0	1 6	2 6	3 4	3 8	4 2	3 0	3 8	5 5	6 2
Riboflavin, mg	2 4	3 2	5 3	6 8	7 5	8 3	7 2	9 0	13 2	15 0
Niacin, mg	16 0	19 2	26 5	34 0	37 5	41 5	30 0	37 5	55 0	62 5
Pantothenic acid, mg	10 0	16 0	23 8	30 6	33 8	37 4	27 0	33 8	49 5	56 2
Pyridoxine, mg	1 2	1 9	—	—	—	—	—	—	—	—
Choline, mg	800 0	—	—	—	—	—	—	—	—	—
Vitamin B_{12}, mcg	20 0	16 0	26 5	—	—	—	—	—	—	—

[a] Source National Research Council (1)

pound of feed was adequate for only 5 of the 10 pigs in the experimental lot. These 5 pigs gained normally and at no time showed any signs of a deficiency. The other 5 pigs, however, showed typical pantothenic acid deficiency symptoms as evidenced by locomotor incoordination. Thus, it must be kept in mind that individual animals vary in their requirements of nutrients. This means that some margin of safety is desirable in compounding rations and especially with nutrients which are not very stable and which may be slowly and gradually destroyed by long storage.

1.6b Variation in Availability of Nutrients in Feeds

Undoubtedly there are differences in the availability of nutrients, depending on their form. There is also a difference between the availability of these nutrients as determined by a chemical analysis or a microbiological assay and as determined by the use the pig will make of them. Their use by the pig may be different from the figures published on the nutrient analyses by various assay methods. This does not mean that analytical values are not valuable—they definitely are. It does mean, however, that some degree of reservation must be exercised and that provision must be made for taking care of this possible difference in availability. Also, a swine feeding trial is the final criterion as to whether a certain combination of feeds mixed by a feeder or feed manufacturer is adequate in certain nutrients. As certain rations vary in their make-up with different feeds, there undoubtedly is some difference in the availability of the nutrients contained therein. This problem needs careful consideration by those concerned with compounding rations.

1.6c Variation in Results with Natural vs. Purified Rations

Most of the nutrient requirements worked out for the pig have been obtained by using purified rations. Yet we apply this information directly to natural or practical rations as fed on the farm. As compared to purified diets, there is some difference in the availability of nutrients in natural rations. Many of the

nutrients, such as vitamins and minerals, are added to purified rations in relatively pure form In natural rations, these vitamins and mineral elements are contained in the feeds in their natural state In most cases, they are in different forms than when they are fed in purified or laboratory diets Thus, there is some difference in their availability and consequently some difference in requirements as worked out with purified and natural rations

There also is apt to be some difference in amino acid requirements as worked out with synthetic amino acids as compared to the need for them when they are supplied in natural or practical rations The digestibility of protein varies, depending on the feed used Thus, amino acid requirements worked out with one ration may not necessarily apply with another kind of ration This means that some care must be used in applying results obtained with purified rations directly to natural rations This does not impair the value of the use of purified rations in nutritional work, but rather indicates that these same nutrients also need to be studied with natural rations The data obtained with purified rations serve as a valuable guide to use in studying the problem with natural rations

1 6d Variation in Deficiency Symptoms

Symptoms for mineral, amino acid, and vitamin deficiencies will be described in Chapters II, III, and IV Single nutrient deficiencies will seldom be encountered under farm conditions In most cases, multiple nutrient deficiencies will occur As a result, a complex deficiency will arise, this may be a combination of symptoms described for various single nutrients or it may be something entirely different Conditions such as reduced appetite and growth or unthriftiness are common to malnutrition in general The nature of the deficiency may be detected only by careful review of the dietary history of the animal and by close observation of the symptoms A fruitful field is open for future studies involving multiple deficiencies such as occur on the farm under varying conditions of feeding Almost no

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1.6c Variation in Results with Natural vs. Purified Rations

Most of the nutrient requirements worked out for the pig have been obtained by using purified rations. Yet we apply this information directly to natural or practical rations as fed on the farm. As compared to purified diets, there is some difference in the availability of nutrients in natural rations. Many of the

nutrients, such as vitamins and minerals, are added to purified rations in relatively pure form. In natural rations, these vitamins and mineral elements are contained in the feeds in their natural state. In most cases, they are in different forms than when they are fed in purified or laboratory diets. Thus, there is some difference in their availability and consequently some difference in requirements as worked out with purified and natural rations.

There also is apt to be some difference in amino acid requirements as worked out with synthetic amino acids as compared to the need for them when they are supplied in natural or practical rations. The digestibility of protein varies, depending on the feed used. Thus, amino acid requirements worked out with one ration may not necessarily apply with another kind of ration. This means that some care must be used in applying results obtained with purified rations directly to natural rations. This does not impair the value of the use of purified rations in nutritional work; but rather indicates that these same nutrients also need to be studied with natural rations. The data obtained with purified rations serve as a valuable guide to use in studying the problem with natural rations.

1.6d Variation in Deficiency Symptoms

Symptoms for mineral, amino acid, and vitamin deficiencies will be described in Chapters II, III, and IV. Single nutrient deficiencies will seldom be encountered under farm conditions. In most cases, multiple nutrient deficiencies will occur. As a result, a complex deficiency will arise; this may be a combination of symptoms described for various single nutrients or it may be something entirely different. Conditions such as reduced appetite and growth or unthriftiness are common to malnutrition in general. The nature of the deficiency may be detected only by careful review of the dietary history of the animal and by close observation of the symptoms. A fruitful field is open for future studies involving multiple deficiencies such as occur on the farm under varying conditions of feeding. Almost no

experimental information is available on multiple deficiencies with the pig.

Nutritional deficiencies may exist without the appearance of definite deficiency symptoms. A nutritional deficiency may show itself only hy slight tissue depletion which may have very little, if any, effect on the performance of the animal. As the deficiency becomes more severe, however, it will affect chemical processes in the body and will eventually result in symptoms which can be observed by looking at the animal.

1.6c Variation in Treatment of Deficiencies

Many nutritional deficiencies produced experimentally can be treated by supplying the missing nutrient. If treatment begins early enough, most—if not all—of the symptoms can usually be cured by supplying the missing substance. This will not always be the case, though, if the deficiency is of long standing and certain changes have occurred in the body which cannot be repaired by feeding the missing nutrient. This must be kept in mind when giving a group of deficient pigs a highly fortified ration to cure nutritional deficiencies. If the pigs have been deficient too long, it may be too late to get them well again, although those which are the least deficient may respond and fatten out well. They should not be depended on, however, for herd replacement animals. Their reproductive systems and possibly other body organs may not be normal enough to produce and wean large and heavy litters. Severe deficiencies never do any animal any good and, in many cases, cause permanent harm. Thus, a good feeding program should eliminate starvation periods, when pigs are allowed to go with very little feed and thus become deficient in certain nutrients.

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CHAPTER II

Protein Requirements of the Pig

2.0 INTRODUCTION

In swine feeding, a lack of protein is most frequently the limiting factor in the ration. This is because farm grains and their by-products are deficient in both quantity and quality of protein for swine. And—since protein supplements are expensive feeds—farmers tend to feed too little protein.

Animals continually use proteins, either to build new tissues, as in growth and reproduction, or to repair worn-out tissues. Thus, swine require a regular intake of protein. If adequate proteins are lacking in a diet, the swine suffer a reduction in growth or loss of weight. Ultimately, protein will be withdrawn from certain tissues to maintain the functions of the more vital tissues of the body as long as possible. Protein is needed to form milk, meat, hide, hoof, hair, hormones, enzymes, blood cells, etc. Thus, protein affects almost every body function. It has been shown also that animals are more resistant to infections if they are fed an adequate protein ration. The elements in the blood stream which resist disease are proteins. So, adequate protein in the diet is one way of keeping animals in disease-fighting trim.

Proteins are made up of many amino acids combined with each other. These amino acids are put together in various combinations to form proteins; they are many times referred to as the building blocks of proteins. Every protein has a definite amino acid composition and no two are alike.

Amino acids contain nitrogen combined with carbon, hydrogen, oxygen, and sometimes sulfur and phosphorus. The nitrogen is in the form of an amino group (NH_2); it is from this that

the name of the amino acid is derived. Amino acids have been commercially synthesized, and a few are available in large quantities. Most amino acids occurring in nature are in the L-form. However, both the D- and L-forms are made in the laboratory. Animals can change the D-form to the L-form with some amino acids but not with others. For example, it has been shown that the rat can use only the L-form of valine, leucine, isoleucine, lysine, and threonine. But, it can use both the D- and L-forms of tryptophan, histidine, phenylalanine, and methionine. This may also be the case with the pig, since his essential amino acid requirements are similar to those of the rat. Information on this point, however, is not yet clear with the pig and awaits further research.

2.1 ESSENTIAL AMINO ACIDS

Animals can make certain of the amino acids from other amino acids or other nutrients in the ration. These are called *nonessential amino acids*. Other amino acids, however, cannot be made in the body from other substances or cannot be made fast

Amino Acid Classification for the Pig

Essential amino acids	Nonessential amino acids
Lysine	Glycine
Tryptophan	Serine
Methionine	Alanine
Valine	N[illegible]leucine
Histidine	[illegible] acid
Phenylalanine	[illegible]ic acid
Leucine	[illegible] glutamic a[illegible]
Isoleucin[illegible]	[illegible]

enough by the animal's body to supply its needs. These are, therefore, known as *essential amino acids.* It has been shown that the pig requires 10 essential amino acids for maximum growth (4,37).

Swine may obtain the nonessential amino acids in the diet or by synthesis in the body from the essential amino acids. An adequate amount of nonessential amino acids in the ration lessens the need for certain essential amino acids by conserving them. For example, cystine is synthesized from methionine. Thus, if the cystine content in the ration is low, there must be enough methionine in the ration to supply the body needs for methionine as well as for the synthesis of cystine. It is more efficient to supply the nonessential amino acids as such rather than through their synthesis from essential amino acids.

2.2 QUALITY OF PROTEIN

Feeds which supply the proper proportions and amounts of the various essential amino acids supply so-called *good quality* protein. Those feeds which furnish an inadequate amount of any of the essential amino acids have *poor quality protein.*

If any one essential amino acid is lacking in proper amount, it will limit the utilization of the other amino acids in the ration. This means that one serious amino acid deficiency will cause the entire ration to be inadequate. For this reason, it is very necessary that feeds low in one or more essential amino acids not be fed alone; otherwise, swine will make poor use of the protein supplied by that feed in performing the body functions which require protein.

Protein supplements are usually slightly low in one or more of the essential amino acids. (See Table V.) Consequently, combinations of protein supplements with other feeds should be fed to make up this deficiency. In most cases, proper selection of feeds accomplishes this. There may be occasions, however, where supplementation of certain rations with synthetic amino acids may be desirable. Recent findings indicate that lower protein rations than used in the past can successfully be

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Amino Acid Classification for the Pig

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Lysine	Glycine
Tryptophan	Serine
Methionine	Alanine
Valine	Norleucine
Histidine	Aspartic acid
Phenylalanine	Glutamic acid
Leucine	Hydroxyglutamic acid
Isoleucine	Cystine[b]
Threonine	Citrulline
Arginine[a]	Proline
	Hydroxyproline
	Tryrosine[c]

[a] Partially synthesized

[b] Can replace 40 to 53 per cent of the methionine requirement.

[c] Can replace part of the phenylalanine requirement.

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fed to pigs. This will be putting more stress on the quality of protein or the essential amino acid content of the ration. Methionine, lysine, and tryptophan are three of the essential amino acids which are apt to be borderline in certain rations; more study is needed to determine the practicality of adding them to swine rations.

2.3 TIME FACTOR IN PROTEIN FEEDING

For efficient use, protein must be present at the right time, in the right amount and balance, as well as in the correct form. A pig cannot consume an excess of amino acids today to take care of tomorrow's needs—amino acids are not stored or carried over. Actually, animals do better if they eat all the required essential amino acids at the same time. The lack of any one essential amino acid will cause the waste of all the others. Proteins are not utilized in the body as such. First they are broken down into amino acids, which are then recombined to form the body's own protein. For protein synthesis, therefore, it is necessary that all the required amino acids be present simultaneously. Tests show (21) that pigs could be fed some corn and protein supplement in the morning and corn alone in the evening with good results (this was an interval of 24 hours between protein supplement feeding). But, when the interval of supplemental protein feeding was increased to 36 hours (2 feedings of corn only, then 1 feeding of corn and protein supplement) or 48 hours (3 feedings of corn, then 1 feeding of corn and

TABLE III. Effect of Feeding Protein at Different Time Intervals (21)

	Corn and supplement fed mixed together	Corn and supplement fed separately		
		Intervals between feeding protein supplement		
		24 hours	36 hours	48 hours
Daily gain, % of initial weight	1 88	1.81	1 64	1 60
Grams gained per kg of feed	3.93	383	350	340
Apparently digested nitrogen retained, %	51.9	51.8	48.3	44.8

protein supplement), a decrease in rate of gain, efficiency of feed utilization, and nitrogen retention resulted (see Table III).

This information indicates that the interval between grain and protein supplement feeding must not be too great. Many swine producers do not realize this fact; they let their pigs suffer from a protein deficiency because they do not fill their protein feeders regularly or do not feed protein supplement to their pigs every day. This also explains why pigs self-fed grain and supplement free-choice usually do better than pigs full-fed grain with the supplement hand-fed.

2.4 EXCESS PROTEIN

Excess proteins are deaminized (the nitrogen removed as ammonia and urea). The remainder of the protein molecule serves as a source of energy or is stored as fat through complex mechanisms in the body. Thus, excess protein is not entirely wasted. However, excess protein should not be fed to supply energy and fat, since it is usually too expensive to do so. Rather, grains and their by-products and other high-carbohydrate feeds, which are cheaper sources of energy, should be used for fattening purposes.

2.5 AMINO ACID REQUIREMENTS OF THE PIG

Experiments at Purdue, Cornell, and Illinois have shown that the pig requires 10 essential amino acids for growth. No information is available on the amino acid requirements for reproduction and lactation. Presumably, the same essential amino acids required for growth are needed, plus others which possibly may not be synthesized fast enough to meet the additonal requirements for reproduction and/or lactation. Table IV shows the essential amino acids required by the young weanling pig as recommended by the National Research Council Committee on Nutrient Requirements for Swine (4).

TABLE IV. National Research Council Recommendations on Essential Amino Acid Requirements for Weanling Pigs (4)

(Live weight—25 to 70 pounds)

Amino acid	Percentage of total diet	Amino acid	Percentage of total diet
l-Arginine[a]	0.20	*dl*-Methionine[b]	0.60
l-Histidine[a,c]	0.40	*dl*-Phenylalanine	0.46
l-Isoleucine	0.70	*l*-Threonine	0.40
l-Leucine[a,d]	0.80	*dl*-Tryptophan	0.20
l-Lysine	1.00	*l*-Valine	0.40

[a] *This level is adequate but minimum requirement has not been established.*
[b] Cystine can replace 40 to 53% of the methionine requirement.
[c] Recent studies at Purdue have shown this requirement to be 0.2% (29).
[d] *Recent studies at Purdue have shown the requirement to be 0.6% (29).*

2.6 EFFECT OF AMINO ACID DEFICIENCIES

This will be discussed for each amino acid. Also, the requirements for each amino acid as obtained by various investigators will be discussed. With some amino acids there are some variations in the requirement figure suggested by different investigators. This is to be expected as is discussed in this chapter in sections 2.8 and 2.10. As more research is conducted, a clearer picture will be obtained on the amino acid requirements of the pig. The difference in ration ingredients accounts for much of the difference obtained in amino acid requirements by various investigators.

2.6a Lysine

Lysine is apt to be borderline or deficient in swine rations, since corn and other cereal grains are generally low in lysine (see Table V). A lysine deficiency (31) results in reduced appetite, loss of weight, poor feed efficiency, rough, dry hair coat, and a general emaciated condition (Fig. 4). The addition of 2.0 per cent DL-lysine to the ration of deficient pigs (31) caused an immediate improvement in growth, appetite, and thriftiness.

With a ration containing 23.8 per cent protein supplied by zein, gelatin, and certain amino acids, Purdue (39) showed that

Fig. 4. Note effect of lysine deficiency in the pig. In 28-day trial the lysine-deficient pig lost 2 pounds, whereas the pig receiving lysine gained 25 pounds. (Courtesy W. M. Beeson, Purdue Agricultural Experiment Station and with the permission of The Macmillan Company, New York, from W. W. Smith, *Pork Production*, Third Edition, copyright 1952.)

weanling pigs performed best on a level of 1.0 per cent L-lysine in the ration. Cornell workers (11) found that weanling pigs

TABLE V. Approximate Amino Acid Composition of Some Hog Feeds (Percentage of Feedstuff)

Feedstuffs	Crude protein, %	Arginine, %	Glycine, %	Histidine, %	Isoleucine, %	Leucine, %	Lysine, %	Methionine, %	Cystine, %	Phenylalanine, %	Threonine, %	Tryptophan, %	Tyrosine, %	Valine, %
Grains and other carbohydrates:														
Barley, exc. l. P.C.	12.7	0.55	0.35	0.24	0.50	0.67	0.40	0.17	0.23	0.56	0.37	0.15	0.22	0.56
Corn, #2, yellow	8.6	0.37	0.36	0.21	0.38	1.23	0.21	0.22	0.11	0.42	0.31	0.07	0.41	0.44
Oats	12.0	0.69	0.28	0.28	0.55	0.86	0.41	0.24	0.21	0.59	0.36	0.15	0.39	0.65
Rye	12.6	0.53	—	0.26	0.53	0.76	0.46	0.17	—	0.62	0.36	0.13	0.23	0.62
Sorghum grain (milo)	11.3	0.45	—	0.24	0.54	1.37	0.28	0.11	—	0.49	0.32	0.11	0.19	0.57
Wheat	15.8	0.61	1.08	0.29	0.51	0.98	0.42	0.23	0.26	0.78	0.42	0.17	0.62	0.69
Potato meal, sweet	7.4	0.21	—	0.10	0.27	0.33	0.28	0.96	—	0.20	0.28	0.13	—	0.41
Potato meal, white	8.2	0.43	—	0.11	0.30	0.48	0.47	0.07	—	0.29	0.21	0.15	—	0.39
Mill concentrates:														
Rice bran	12.8	0.49	—	0.15	0.40	0.55	0.42	—	0.11	0.37	0.28	0.10	—	0.56
Rice polish	12.4	0.45	—	0.10	0.32	0.46	0.45	—	0.13	0.32	0.24	0.13	—	—
Wheat standard middlings	17.6	0.95	0.48	0.46	0.84	0.99	0.46	0.28	0.24	0.76	0.46	0.20	0.23	0.91
Wheat red dog	18.3	0.69	—	0.46	0.77	1.00	0.54	0.15	—	0.39	0.46	0.15	0.15	0.92
Wheat bran	16.4	0.99	0.91	0.35	0.67	0.96	0.53	0.21	0.26	0.49	0.39	0.22	0.18	0.77
Protein supplements (plant):														
Cottonseed meal (41%)	41.0	3.93	2.17	0.98	1.57	2.67	1.61	0.66	0.82	2.14	1.35	0.57	0.96	1.93
Linseed meal (35%)	35.4	2.87	—	0.82	1.69	2.04	1.09	0.67	0.58	1.78	1.26	0.51	1.81	2.02
Peanut meal (41%)	41.6	4.27	—	0.84	1.44	2.34	1.28	0.49	—	2.12	0.94	0.40	—	1.71

Soybean meal (exp hyd 41%)	42.0	2.98	—	1.03	2.30	3.21	2.53	0.50	0.80	2.05	1.60	0.60	0.89	2.22
Soybean meal (solv 43%)	46.0	3.06	—	1.16	2.67	3.73	2.98	0.52	—	2.04	1.99	0.84	0.87	2.50
Distillers' solubles, dried	28.0	0.68	—	0.74	1.52	1.93	0.84	0.43	0.28	1.73	0.92	0.12	0.61	1.42
Yeast, brewers', dried	46.8	—	—	0.75	2.32	3.14	3.37	0.86	—	1.73	2.48	0.17	1.36	2.48
Protein supplements (animal)														
Buttermilk, dried	32.4	1.00	—	0.84	2.42	3.09	2.17	0.67	—	1.34	1.42	0.42	0.92	2.51
Fish meal, menhaden	62.2	3.53	—	1.59	3.65	5.08	5.49	1.80	—	2.70	2.51	0.50	1.91	3.86
Fish meal, sardine	67.2	4.30	—	1.68	3.70	4.81	5.91	2.35	0.81	2.82	2.82	0.87	2.96	4.07
Meat & bone scrap (50%)	50.6	3.59	—	0.81	1.65	2.94	2.68	—	—	1.82	1.65	—	—	2.38
Meat meal (60%)	60.9	3.79	—	1.68	2.94	4.87	3.98	1.13	0.61	2.93	2.29	0.41	1.66	3.62
Skimmed milk, dried	34.7	1.08	—	0.93	2.24	3.06	2.53	0.78	—	1.57	1.60	0.44	1.36	2.39
Tankage (60%)	60.6	3.62	—	1.59	1.89	5.15	3.68	0.60	—	2.74	1.94	0.45	1.81	3.35
Whey, dried	12.2	0.22	—	0.15	0.74	1.00	0.58	0.32	—	0.38	0.58	0.25	0.07	0.68
Miscellaneous														
Alfalfa meal, sun cured (17%)	17.6	0.71	—	0.44	0.80	1.14	0.76	0.31	0.23	0.75	0.58	0.30	—	0.75
Alfalfa leaf meal, sun cured (20%)	20.9	1.23	—	0.32	1.06	1.31	1.05	0.27	0.73	0.88	0.67	0.36	0.74	1.21
Alfalfa meal, dehydrated (17%)	17.8	0.55	—	0.29	0.90	1.16	0.75	0.32	0.25	0.76	0.60	0.27	—	0.75
Fish solubles	30.7	0.98	—	1.53	0.59	0.62	0.92	0.31	1.23	0.47	0.42	0.34	0.23	0.81

Note The data on amino acid composition of feedstuffs are taken from compilations in the laboratories of the Bureau of Animal Industry, U S D A, that appeared in National Research Council Publication on Nutrient Requirements for Swine (4)

required 0.6 per cent L-lysine in the ration when a 10.6 per cent linseed meal protein ration was used and 1.2 per cent L-lysine when a 22 per cent protein sesame meal ration or a 22 per cent mixture of meat scraps, zein, and wheat protein ration was fed. The difference in these requirements is largely eliminated, however, if they are expressed in terms of their proportion to the protein in the rations. The lysine requirements of 0.6 and 1.2 per cent of the ration correspond to 5.7 and 5.5 per cent of the protein in the 10.6 and 22.0 per cent protein rations, respectively (this will be discussed further in section 2.9).

Missouri (34) workers found that pigs from weaning to about 100 pounds live weight—fed rations of corn, soybean meal, tankage, and wheat shorts—appeared to have their requirements met by 5.0 per cent L-lysine, expressed as a per cent of the protein in the ration. They also found that some pigs on the unsupplemented rations grew at faster rates than their litter mates receiving lysine. This indicates that the lysine requirement is variable between pigs even in the same litter. This means that the variability within litters must be reduced if lysine requirements are to be determined as an exact figure and not as an approximation.

Illinois workers (2) found that pigs from 40 to 100 pounds performed satisfactorily on a corn-soybean oil meal ration containing 14 per cent protein and 0.63 per cent lysine, whereas pigs from 100 to 200 pounds needed 12 per cent protein and 0.52 per cent lysine. The Illinois workers also point out that corn is markedly low in lysine and tryptophan. So the higher the level of corn used in the ration, the lower will be the per cent of these two amino acids in the ration. As diets lower in protein are used there will be a higher level of corn used in the ration.

This problem is accentuated when high-protein corn is used. The higher the protein level in corn, the lower the amount of soybean oil meal needed to balance the corn. This means the ration contains a higher percentage of corn and less soybean oil meal. This, in turn, results in a ration even lower in lysine and

tryptophan The figures in Table VI illustrate this point Hence, swine husbandmen would be wise to feed enough protein and amino acids to include a margin of safety which would allow for the wide variation which exists in the protein content of corn This variation ranges from about 6 5 to 11 per cent protein, and even higher, in the United States Lysine supplementation has been beneficial with corn-"low gossypol" cottonseed meal rations (20,32)

TABLE VI –Effect of Corn Protein Level on Lysine and Tryptophan in Ration (1)

Protein in corn, %	7 4	8 5
Protein in ration, %	14	14
Corn protein in total ration, %	41 0	48 8
Lysine in ration, %	0 63	0 60
Tryptophan in ration, %	0 13	0 12

2 6b Tryptophan

Tryptophan is another of the essential amino acids which is apt to be low or borderline in certain swine rations, since corn is low in tryptophan A lack of tryptophan (Fig 5) causes a loss in weight, poor feed consumption, depraved appetite, rough hair coat, and symptoms of inanition in the pig (7,8) Adding tryptophan to the ration of deficient pigs caused an immediate response and recovery

An interrelationship exists between niacin and tryptophan Pigs can use tryptophan to synthesize niacin Niacin, however, cannot be converted back to tryptophan Consequently, an adequate level of niacin in the ration spares tryptophen, since tryptophan will not be used to make niacin If the tryptophan is at a high enough level in the diet, animals will probably not develop a nicotinic acid deficiency For example, swine will develop a nicotinic acid deficiency on a low-protein diet, but not if the diet contains 25 or 26 per cent casein (which is high in tryptophan) Thus, when studying the niacin requirement, use rations which are just adequate in tryptophan When studying

the requirements for tryptophan, use rations which are adequate in or contain an excess of niacin.

Purdue workers (40) observed that a 0.2 per cent level of DL-tryptophan permitted more rapid growth than a 0.1 per cent

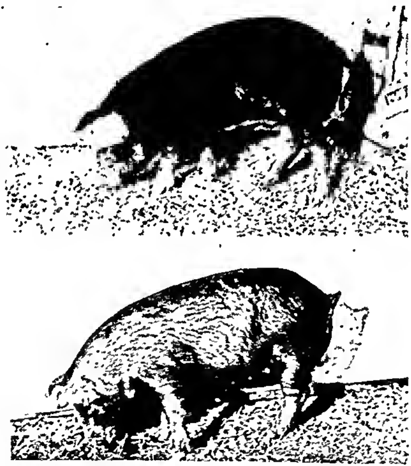

Fig. 5. Tryptophan deficiency. In 21-day trial the tryptophan-deficient pig shown in top of photo lost 8 pounds while the tryptophan-supplemented pig gained 25.5 pounds. (Courtesy W. M. Beeson, Purdue Agricultural Experiment Station.)

level when added to a tryptophan-deficient diet containing approximately 24.5 per cent protein and adequate niacin. Recently, Illinois workers (3), also using weanling pigs, showed

that the L-tryptophan requirement of the pig, in the presence of adequate niacin, is 0.115 per cent of a corn-menhaden fish meal ration containing 15.3 per cent protein. They also showed that the pig can use a considerable share of the D-tryptophan as found in a racemic-amino acid mixture. It was also found that the thyroid gland, when expressed as a percentage of the carcass weight, was significantly larger in the tryptophan-deficient pig.

In another Illinois experiment (2), it was shown that a tryptophan level of 0.13 per cent was adequate for 40- to 100-pound pigs and 0.10 per cent was adequate for 100- to 200-pound pigs. In this experiment, the pig from 40 to 100 pounds live weight required a minimum of 14 per cent protein in a corn-soybean oil meal ration and a minimum of 16 per cent protein in a corn-menhaden fish meal ration. From 100 to 200 pounds live weight, the pig needed a minimum of 12 per cent protein when either soybean oil meal or menhaden fish meal was used as the source of supplementary protein with yellow corn. Missouri workers (34) showed that pigs from weaning to about 100 pounds fed rations of corn, soybean oil meal, tankage, and wheat shorts appeared to have their requirements met by 1.0 per cent tryptophan, expressed as a per cent of the protein in the ration.

2.6c Methionine

Methionine is another essential amino acid which might occasionally be borderline in certain swine rations. A lack of methionine results in reduced rate of gain and efficiency of feed utilization (9,38). Workers at Purdue (38), Cornell (18), and Illinois (1) showed that cystine can replace 50, 53, and 40 per cent, respectively, of the methionine in the ration for the young pig. Pigs do not require cystine in the ration if they have sufficient methionine to meet their requirements for both methionine and the synthesis of cystine. This is important because, when an adequate amount of cystine is included in the ration, methionine is no longer converted to cystine. Instead, it is used as methionine to form new tissue and carry out the

other functions for which methionine is essential. Using soybean oil meal with corn results in rations which are occasionally borderline in methionine. However, there are conflicting experimental results on the value of adding methionine to corn-soybean oil meal rations for swine. These differences may be due to variation in the methionine content and its availability in soybean oil meal. It is possible that methionine supplementation may be beneficial with improperly processed soybean meal but of no help with properly prepared meals. More experimental work is needed on this problem.

An interrelationship exists between methionine and choline. Methionine can furnish methyl groups for choline synthesis. In a diet which is mildly deficient in both, adding either one will improve growth. Methionine is effective both in correcting a methionine deficiency and in promoting the synthesis of choline. For example, Illinois workers (33) have shown no demonstrable dietary choline requirement for the baby pig on a synthetic milk diet containing 1.6 per cent methionine. With 0.8 to 1.0 per cent methionine in the diet, however, the baby pig requires choline at a level of approximately 0.1 per cent of the dry matter of the diet.

Choline is effective only in sparing methionine. Thus, with an adequate level of choline in the ration, methionine is not used for choline synthesis. There also seems to be an interrelationship between B_{12} and methionine needs of the pig (17,35). More work is needed on this point, however.

Purdue workers (38) found, with a 21 per cent protein ration, that the level of methionine which supported the best rate of gain and feed efficiency was 0.6 per cent of the diet when 0.01 per cent cystine was present in the ration. Cornell workers (19) found that the methionine requirement does not exceed 0.31 per cent when the ration contains 0.38 per cent cystine and 22 per cent protein. Illinois workers (1) showed that a level of 0.25 per cent methionine, in the presence of 0.17 per cent cystine, supported satisfactory rate and efficiency of gain with a 12.6 per cent protein ration. Expressed as a percentage

of the dietary protein, the combined methionine-cystine requirement in the Illinois study is approximately 3.33 per cent of the protein. This value compares with 2.86 and 3.18 per cent of the dietary protein found by the Purdue (38) and Cornell (19) workers, respectively. Thus, the methionine needs obtained by these three groups of investigators are not too far different when expressed as a percentage of the protein in the ration.

Missouri workers (34) have shown that pigs from weaning to 100 pounds—fed rations of corn, soybean oil meal, tankage, and wheat shorts—appeared to have their requirements met by 3.5 per cent methionine, expressed as a per cent of the protein in the ration. The Illinois Station (2) has shown that 40- to 100-pound pigs performed satisfactorily when fed corn-soybean rations containing 14 per cent protein and 0.23 per cent methionine. Pigs from 100 to 200 pounds performed well on 12 per cent protein and 0.21 per cent methionine.

The weanling pig can utilize DL-alpha-hydroxy-gamma-methylmercapto butyric acid to satisfy at least partially the methionine requirement for normal growth (1).

2.6d. Histidine

Histidine is usually supplied in adequate amounts in practical swine rations. A deficiency of histidine in the ration resulted in decreased growth and efficiency of feed utilization (22). When histidine was added to the diet of deficient pigs, they showed greatly increased appetites and resumed growth almost immediately. Recently, the Purdue Station (29) has shown the L-histidine requirement of weanling pigs to be 0.2 per cent with a 13 per cent protein ration.

2.6e. Phenylalanine

Phenylalanine is usually adequately supplied in practical swine rations. A deficiency of phenylalanine in the pig resulted in decreased growth and efficiency of feed utilization (28). Although it has not been conclusively determined, it is possible

that tyrosine can replace about 30 per cent of the phenylalanine requirement of the pig (6). Tyrosine is synthesized from phenylalanine. This means that if the ration contains sufficient tyrosine, phenylalanine will not be used up for the synthesis of tyrosine. If the ration is short of tyrosine, then phenylalanine will be used for tyrosine synthesis.

Purdue workers (30) using a 12.6 per cent protein ration showed that maximum gains and feed utilization were obtained with 0.32 per cent phenylalanine and 0.14 per cent tyrosine in the ration. Assuming that the 0.14 per cent tyrosine substituted for an equal weight of phenylalanine, the phenylalanine requirement of the weanling pig is 0.46 per cent of the ration. This value is equivalent to 3.6 per cent of the protein in the ration.

2.6f Arginine

Arginine is not apt to be deficient in practical swine rations. A deficiency of arginine causes slower growth and lowered efficiency of feed utilization with the pig (28). Arginine can be synthesized at a rate sufficient to permit about 60 per cent of normal growth (28). Pigs need a dietary source of arginine, however, for maximum growth. No minimum levels have been established for an arginine requirement, but a level of 0.20 per cent L-arginine in the ration, or 1.77 per cent of the protein, is adequate to meet the pig's needs along with the amount synthesized by the pig (28).

2.6g Leucine

Leucine is present in sufficient quantity in feeds to meet the requirements of the pig. A deficiency of leucine in the pig caused a decrease of appetite, feed efficiency, and rate of gain (28,29). Cornell workers (23) showed that the L-leucine requirement of the suckling pig (starting weight of 2.5 pounds) is more than 1.0 but does not exceed 1.25 per cent of the diet. This is equivalent to not more than 5.0 per cent of the protein in the ration.

Purdue workers (29) recently found the L-leucine requirement of the weanling pig fed a 13 per cent protein ration to be 0.6 per cent. This is equivalent to 4.61 per cent of the protein in the diet. In view of the differences in ages of the pigs, this value is in fairly close agreement with the Cornell figure.

2.6h Isoleucine

Isoleucine is not apt to be deficient in practical swine rations. Cornell workers (10) showed that a lack of isoleucine in the ration

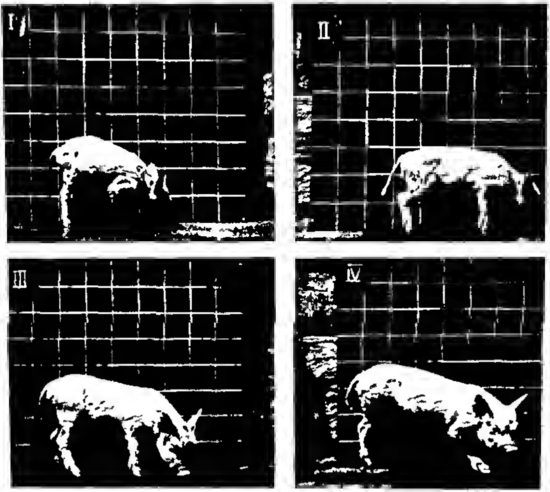

Fig 6. These pigs illustrate the striking growth response from adding threonine to the ration. The pigs received the following levels of l-threonine. Pig 1, 0.36 per cent of the dry matter of the diet; Pig 2, 0.54 per cent; Pig 3, 0.73 per cent; and Pig 4, 0.92 per cent. (Courtesy J K. Loosli, Cornell Agricultural Experiment Station and *Journal of Nutrition*.)

decreased rate of gain, efficiency of feed utilization, and nitrogen retention. They also found that weanling pigs fed a 22 per cent protein ration required 0.7 per cent L-isoleucine. This is equivalent to 3.18 per cent of the dietary protein.

2.6i Threonine

Threonine is present in sufficient quantity in feeds adequately to meet the requirements of the pig fed practical rations. A deficiency of threnine decreases feed consumption, rate of gain, and efficiency of feed utilization (2,5,36). Cornell workers (36) showed that the suckling pig (4 pound starting weight), fed a simulated milk diet containing approximately 25 per cent protein, requires approximately 0.9 per cent L-threonine in the ration (Fig. 6). This is equivalent to 3.6 per cent of the dietary protein. The Purdue Station (5) has shown that the weanling pig fed a 13.2 per cent protein ration required 0.4 per cent of L-threonine in the ration. This is equivalent to 3.0 per cent of the protein in the ration.

2.6j Valine

Valine is not apt to be deficient in practical swine rations. A deficiency of valine in the ration decreased daily feed consumption, rate of gain, and feed efficiency (25,28). Purdue workers (25) showed that weanling pigs fed a 12.8 per cent protein ration require 0.4 per cent L-valine in the diet. This is equivalent to 3.1 per cent of the protein in the ration.

2.7 UREA AS PROTEIN SUBSTITUTE

Minnesota workers (24) found that the addition of 1.5 per cent urea to a low-protein (10.6 per cent) ration for weanling pigs had no significant effect on daily feed consumption or rate of gain. The pigs fed urea required 6 per cent more feed per pound of gain. There was no clinical evidence of toxicity at any time in any of the pigs fed urea. This means that cattle feeds (removed from feed troughs and not consumed by the cattle)

containing low levels of urea (1.0 to 1.5 per cent) can be fed to swine without risk of toxicity. Iowa studies (27) showed that there is a small, but definite, amount of administered urea incorporated into the body protein of the pig. With present information, it appears that urea should not be added to swine rations.

The information on the requirements for essential amino acids indicates that three are apt to be borderline or limiting in swine rations. They are tryptophan, lysine, and methionine. It is possible that histidine may occasionally be borderline. Further research is needed, however, to clarify this possibility.

TABLE VII

Combination[a]	Most probable limiting amino acids
Corn + cottonseed meal	Lysine and tryptophan
Corn + linseed meal	Lysine and tryptophan
Corn + fish meal	Tryptophan
Corn + meat and bone scraps	Tryptophan
Corn + tankage	Tryptophan
Corn + soybean oil meal	Methionine
Corn + peanut meal	Methionine and lysine and tryptophan

[a] These predictions are not absolute, since feeds vary considerably in amino acid composition depending on their origin, method of processing, temperatures used in processing, and many other factors. It is also possible that other amino acids might be limiting with some of the combinations shown above. However, this information can be used as a guide as to the most probably limiting amino acids with an 18 per cent protein ration.

By studying the amino acid content of feeds in Table V, the following combinations of corn and protein supplements (shown in Table VII) will result in certain amino acid deficiencies which are apt to be encountered in feeding swine.

2.8 BALANCE OF AMINO ACIDS

The balance of amino acids in the ration is very important. For example, a recent Arkansas study (32) showed that pigs benefited from receiving 0.1 per cent level of DL-lysine with a

corn-cottonseed meal ration. Levels of lysine greater than 0.1 per cent appeared to depress growth; whereas levels lower than 0.1 per cent failed to support maximum growth. Many other investigators have obtained similar results. This means that if one adds an amino acid to a ration and the pig does not respond, the ration may still lack the amino acid. To definitely determine the need for an amino acid various levels of the amino acid as well as different protein content rations—and in some cases other possible limiting amino acids in various combinations and levels—must be fed to test all possibilities.

In other words, determining the need for amino acids in rations is difficult and much more time-consuming than determining vitamin or mineral response. Evidently, amino acids need to be fed at the right level and also in the right proportion, and at the right time, with the other amino acids for maximum response. Moreover, the requirement for amino acids varies not only with the type of diet used and the relative supply and availability of the amino acids, but also with the dietary supply of other essential substances which can, in case of need, be made from an amino acid. The complexity of the amino acid supplementation problem undoubtedly accounts for the inconsistent results which have been obtained by many workers in supplementing swine rations. Sometimes these workers got beneficial effects and other times they did not.

2.9 AMINO ACID NEEDS EXPRESSED AS PER CENT OF PROTEIN IN RATION

As the protein content of the ration increases, some investigators feel that the percentage of the amino acid needed in the diet also increases. For example, Cornell workers (11) found that, as the protein content of the diet increased from 10 to 22 per cent, the lysine requirement for growth of the pig increased from 0.6 to 1.2 per cent of the ration. Expressing the amino acid requirements as a percentage of the protein rather than as a percentage of the diet greatly reduces the differences in amino acid needs determined with different protein levels in the ration.

For example, on the 10.6 per cent protein diet, the lysine requirement of 0.6 per cent is equivalent to 5.7 per cent of the protein, and on the 22 per cent protein diet the requirement of

TABLE VIII. Essential Amino Acid Requirements of the Weanling Pig (Live weight—25 to 70 pounds)

Amino acid	Protein level at which amino acid requirement was determined, %	Amino acid requirements[c] based on		Calculated amino acid[d] requirements for total ration—protein contents of				
		Protein in the ration, %	Total ration, %	18%	16%	14%	12%	10%
l-Arginine[a]	11.3	1.77	0.20	0.32	0.28	0.25	0.21	0.18
l-Histidine	13.0	1.54	0.20	0.28	0.25	0.22	0.18	0.15
l-Isoleucine	22.0	3.18	0.70	0.57	0.51	0.45	0.38	0.32
l-Leucine	13.0	4.61	0.60	0.83	0.74	0.65	0.55	0.46
l-Lysine	23.8	4.20	1.00	0.76	0.67	0.59	0.50	0.42
dl-Methionine[b]	21.0	2.86	0.60	0.51	0.46	0.40	0.34	0.29
dl-Phenylalanine	13.0	3.54	0.46	0.64	0.57	0.50	0.42	0.35
l-Threonine	13.2	3.03	0.40	0.55	0.48	0.42	0.36	0.30
dl-Tryptophan	24.5	0.82	0.20	0.15	0.13	0.11	0.10	0.08
l-Valine	12.8	3.12	0.40	0.56	0.50	0.44	0.37	0.31

[a] This level is adequate but minimum requirement has not been established.

[b] Cystine can replace 40 to 53% of the methionine requirement.

[c] Based on National Research Council Recommendations (4) except values for histidine and leucine. When the National Research Council recommendations were made, the requirements for histidine and leucine had not yet been worked out.

[d] *Note:* This is assuming that the amino acid requirement is about directly proportional to the protein level fed. These figures for amino acid requirements might vary somewhat depending on the percentage of protein in the ration. However, these figures can be used as a rough guide, with the reservation that they may not be entirely correct. It may be possible that the amino acid requirement will apply correctly only at the level of protein feeding under which it was determined and also under the same conditions. There is some evidence with other animals that, whereas the total requirement of amino acid decreases with decreasing protein level, the percentage of the amino acid that must be present in the protein for maximum growth may increase as the protein level decreases.

1.2 per cent lysine is equivalent to 5.5 per cent of the dietary protein. Table VIII shows the essential amino acids needed by the pig expressed in percentage of the diet and in percentage of the protein in the ration.

2.10 PROTEIN REQUIREMENTS OF THE PIG

Recent advances in the use of antibiotics and in vitamin and mineral nutrition have made it possible to feed less protein in swine rations. During the past few years, considerable re-evaluation of protein requirements has been made. It is not clear yet how much of this protein-sparing effect is due to antibiotic feeding and how much to a ration more adequate in vitamins (B_{12}, riboflavin, niacin, and pantothenic acid) or certain mineral elements. However, considerably less protein is needed now with proper ration fortification. Evidently, protein requirements have been high in the past because the protein supplements were supplying factors other than amino acids (such as vitamins and minerals).

As more information is obtained on (*1*) the amino acid content, availability, and variation in feeds, (*2*) the amino acid requirements of the pig at various stages of its life cycle, (*3*) the amino acid balance and its interrelationships with other amino acids and other nutrients, and (*4*) the effect of processing on the nutritive value of protein and amino acids, it is possible that protein requirements of the pig will be lowered even further.

In other words, protein needs will be thought of in terms of supplying adequate amounts and proper balance of the essential amino acids. For example, Purdue workers (28) found that if the 10 essential amino acids were fed at the proper balance and level, a 30-pound weanling pig could grow normally on 7.4 per cent protein equivalent from amino acids and 3.9 per cent protein equivalent from diammonium citrate. This ration had an equivalent of only 11.3 per cent crude protein. The pigs on this ration gained 1.12 to 1.29 pounds daily, which is above the average for pigs of that weight on practical rations.

The Purdue work was conducted with a synthetic diet which

is far from a practical ration. However, it can be used as an indication to show that the high level of protein previously required by pigs was due to poor-quality protein which was not supplying a proper amount and balance of all amino acids. This work also serves to illustrate the possibilities of reducing the protein requirements of swine rations in the future by proper supplementation with amino acids.

In discussing the protein requirements of the pig, we must realize that young pigs require more protein in the ration than older animals which are storing less protein and more fat in their bodies. Many feeders overlook this fact and feed pigs the same proportion of protein supplement from weaning time to market. If the ration supplies enough protein for the young pig, there will be considerably more than is needed after the pigs weigh 75 or 100 pounds. Likewise, if the ration supplies only enough protein for a 100- or 125-pound pig, then the young, weanling pig will have too little protein. This means that complete rations (grain and protein supplement mixed) should have

TABLE IX. National Research Council Recommendations on Protein Requirements of the Pig (4)

	Live weight lb	Total feed intake, lb	Crude protein content of ration, %	Crude protein needed daily, lb
Market stock	25	2 0	18	0.36
Market stock	50	3 2	16	0.51
Market stock	100	5 3	14	0.74
Market stock	150	6.8	13	0.88
Market stock	200	7.5	12	0 90
Market stock	250	8.3	12	1.00
Pregnant females and breeding boars				
Young stock	300	6 0	15	0.90
Adults	500	7.5	14	1.05
Lactating females				
Gilts	350	11.0	15	1.65
Sows	450	12.5	14	1.75

different protein contents and be designed specifically for pigs in different weight groups. Table IX shows the protein requirements recommended by the National Research Council Committee on Nutrient Requirements for Swine (4).

The protein levels recommended by the National Research Council are higher than the levels suggested by several workers (2,12–16,26,34). For example, the following protein levels have been satisfactory in many feeding experiments.

Weight of pig	Per cent crude protein*
Weaning to 75 lb.	14
75 to 125 lbs	12
125 to 200 lbs.	10

* Needed in the ration properly fortified with antibiotics, vitamins, and minerals.

These lower levels of protein, however, contain no margin of safety. Besides, these experiments were conducted under excellent conditions of sanitation and management. The feeds used were of excellent quality and all rations were fortified with suitable levels of antibiotics, vitamins, and minerals. This means these protein levels were satisfactory under the best of conditions. Under average farm conditions, management and/or sanitation is not always what it should be. Moreover, the quality of feeds and their proper fortification with vitamins, antibiotics, and minerals may not be adequate. Natural feeds vary considerably in their amino acid content and needs of pigs also vary depending on many factors. Thus, protein requirements would tend to be higher on the average farm than under the optimum conditions found at an experiment station. This is the reason for the larger figures on protein requirements of the pig recommended by the National Research Council (4).

The National Research Council recommendations may be lowered as the new developments in vitamins, antibiotics, and minerals become more widely known and applied by those

concerned directly and indirectly with swine feeding Again, remember that grains will vary in protein and amino acid content depending upon the area of the country in which they are grown, and a safety factor must be provided to take care of this extreme variation This fact also presents an opportunity for plant breeders and geneticists to pay more attention to the amino acid and protein composition of the new varieties of plants developed in the future Enough information is already available to indicate that much progress can be accomplished through breeding and selection for feeds with higher levels and higher quality protein for swine feeding

2 11 ENERGY-PROTEIN RATIO RELATIONSHIPS

The ratio between energy and protein in poultry feeds has received a considerable amount of attention recently As the energy level of the feed is increased, the level of other critical nutrients, including protein, should be increased accordingly This insures that these nutrients are supplied in proper amounts and balance to meet the bird's requirement For example, University of Maryland studies have shown that a ratio of approximately 42 calories of productive energy per pound of ration for each per cent protein is satisfactory for broiler starting rations Broiler finishing rations, however, should contain approximately 48 to 50 calories of productive energy per pound for each per cent of crude protein in the ration

Some work has also been done with poultry on relating methionine needs to the calories in the ration This is a relatively new field, but it should be watched by the researcher in swine nutrition It is possible that as amino acid requirements become more refined and accurate they may be worked out in relation to the available energy in the ration

2 12 ESTIMATION OF GROWTH REQUIREMENTS FOR AMINO ACIDS BY ASSAY OF THE CARCASS

The Cornell Station (41) has summarized data on the estimated amino acid requirements of the pig based on carcass

analyses (see Table X). Their data on the amino acid content of swine tissues at various ages would indicate that the requirements for the various amino acids at different stages of growth may not vary markedly when expressed as a per cent of the dietary protein. The data in Table X on the calculated amino acid requirements of the pig, based on carcass analyses, show a

TABLE X. Amino Acid Content of Pig Carcasses and Estimated Requirements for Growth Based Thereon (41)

Amino acid	Amino acid content of pig carcasses*	Calculated requirement, % of diet	National Research Council recommendations (4)
Arginine	7.12	0.91	0.20
Histidine	2.65	0.34	0.40
Isoleucine	3.84	0.50	0.70
Leucine	7.14	0.92	0.80
Lysine	8.55	1.10	1.00
Methionine	1.77	0.23	0.60
Phenylalanine	3.77	0.48	0.46
Threonine	3.79	0.48	0.40
Tryptophan	0.74	0.10	0.20
Valine	6.00	0.77	0.40
Tyrosine	2.59	0.33	
Cystine	1.01	0.13	
Methionine + cystine	2.78	0.36	
Phenylalanine + tyrosine	6.36	0.81	

* The amino acids are given as grams per 16 grams of nitrogen. This figure represents an average of analyses obtained for a newborn, weanling, 73 lb. pig, and a 205-lb. pig.

degree of similarity to the nutritionally determined amino acid requirements recommended by the National Research Council. With certain amino acids, this similarity is rather close, whereas with others it is not. These studies would indicate that the amino acid content of swine carcasses can be used as a guide in determining the levels of amino acids to use in studying the nutritional requirements of the pig for them.

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CHAPTER III

Mineral Requirements of the Pig

3.0 INTRODUCTION

Mineral deficiencies still cost swine producers large sums of money each year. This is an unnecessary loss. Minerals are cheap and can be fed easily to all classes of swine.

3.1 RELATION OF SOIL MINERALS TO SWINE FEEDS

Soils in the United States are declining in fertility. In a single human generation, the soil fertility on a farm can be depleted by failure to add crop residues, manure, and other forms of plant foods. Many animal ailments—which are on the increase—may be due in part to declining soil fertility. As this decline increases, farmers will have to supply not only minerals now deficient but also other minerals which may eventually become low in the soil. It is not enough to think of feeding minerals to livestock. We should also think of adding minerals to the soil, which is gradually becoming depleted. Minerals added to depleted soils bolster the mineral content of plants grown thereon. Added minerals also increase the tonnage yield of the forage and other nutrients in the plant.

3.2 FORCED PRODUCTION AND CONFINED CONDITIONS INCREASE MINERAL NEEDS

Farmers are demanding and obtaining higher production rates; in turn, this has increased the mineral needs of swine. For example, using antibiotics and adequate vitamin supplementation has increased the growth rate of swine. This more rapid growth undoubtedly has affected mineral requirements and suggests a need for re-evaluating presently recommended levels.

Likewise, the increased feeding of swine in close confinement has made it even more essential to feed rations adequate in minerals. Forced production, close confinement, and declining soil fertility increase the need to supply adequate minerals in the ration.

3.3 THE VITAL FUNCTIONS OF MINERALS AND EFFECTS OF DEFICIENCY

Minerals perform important functions in the animal's body. Besides being constituents of bone and teeth, mineral elements

Fig. 7. A cause of posterior paralysis. Split section of backbone of pig, showing a fractured lumbar vertebra. When a vertebra collapses, it presses on the spinal cord and thus causes paralysis of the rear extremities. This is referred to as "going down in the back." It is caused by a calcium, phosphorus, or vitamin D deficiency. (Courtesy G. Bohstedt and Ohio Agricultural Experiment Station, and with the permission of The Macmillan Company, New York, from W. W. Smith, *Pork Production*, Third Edition, copyright 1952.)

serve the body in many other ways. Nearly every process of the animal body depends on one or more of the mineral elements for proper functioning. Minerals are just as essential for growth, reproduction, and lactation as are proteins, fats, carbohydrates, and vitamins.

A lack of minerals in the ration may cause any of the following deficiency symptoms: reduced or poor appetite; expensive, poor gains; rickets; soft or brittle bones; beading of the ribs; stiffness or malformed joints; posterior paralysis ("going down in the back"); goiter; animals which are rough, unthrifty looking; pigs born hairless; failure to come in heat regularly; poor milk production; weak or dead young; and many other ailments (1,2,7–9,15,35). Thus, it is not too surprising that a pig fed

a mineral-deficient ration will eventually die if the deficiency is severe enough and is not corrected

Fig 8 Why hogs break their legs Note abnormal thigh bone on right The thickness of the bone is no indication of its strength Nature has thickened the bone so as to help overcome its weakness, which is evident from the spontaneous fracture near its middle A pig with such a thigh bone is a cripple, walking with difficulty This is due to a lack of calcium and phosphorus (Courtesy of G Bohstedt and Ohio Agricultural Experiment Station and with the permission of the Macmillan Company, New York, from W W Smith, *Pork Production*, Third Edition, copyright 1952)

3.4 THE MINERAL CONTENT OF THE ANIMAL BODY

Calcium and phosphorus make up over 70 per cent of the ash in the body. For the most part, these two mineral elements oc-

cur in the body combined with each other. An inadequate supply of either one in the ration will limit the utilization of the other. Approximately 80 per cent of the phosphorus and 99 per cent of the calcium in the body is present in the bones and teeth. These figures indicate the importance of calcium and phosphorus in the ration and the role they play in giving rigidity and strength to the skeletal structure. Although the other minerals are contained in smaller amounts in the animal's body, their presence is just as important as that of calcium and phosphorus.

3.5 ESSENTIAL MINERAL ELEMENTS AND THOSE APT TO BE DEFICIENT

At present, the following 13 mineral elements have been shown to perform essential functions in the body. They thus must be present in the ration: calcium, phosphorus, sodium, chlorine, copper, iron, cobalt, iodine, manganese, magnesium, sulfur, zinc, and potassium. Fluorine might also be included in the list of essential mineral elements. At high levels it is harmful, but at low levels it has decreased tooth decay; this means it affects teeth beneficially in some manner. Molybdenum has recently been found to be an enzyme constituent. Thus, it might also be classified as an essential mineral element. It is also possible that other minerals may be essential in the body.

Of the essential mineral elements, eight are likely to be deficient in swine rations. These are calcium, phosphorus, sodium, chlorine, cobalt, iron, copper, and zinc. So far as is known, deficiencies of the other five essential mineral elements are not encountered, since the feeds used contain them in sufficient quantities. It may be that as our soils decline in fertility other mineral elements may become deficient in swine rations.

3.6 CALCIUM AND PHOSPHORUS

These two minerals are discussed together because there is a close relationship between them. Calcium and phosphorus make

up over one-half of the minerals in milk They also comprise about three-fourths of the minerals in the entire body of an animal Thus, it is important to supply these two minerals in swine rations Swine suffer more from a lack of calcium than from the lack of any other mineral, with the exception of common salt

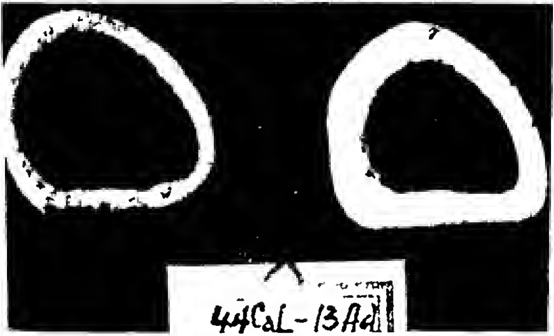

Fig 9 Calcium deficiency Cross section of leg bone Note the thickness and strength of the bone from the pig fed an adequate calcium ration as compared to that of a calcium deficient pig on the left (Courtesy A G Hogan Missouri Agricultural Experiment Station)

3 6a Calcium Most Apt To Be Lacking

There is more likely to be a deficiency of calcium than of phosphorus in swine rations This is because grain and protein supplements make up a very large portion of the feed consumed by these animals By comparing the content of feeds and the requirement of the pig for calcium and phosphorus, one can readily see why calcium is most apt to be lacking in swine rations Cereal grains, which make up the bulk of swine rations, are quite low in calcium

cur in the body combined with each other. An inadequate supply of either one in the ration will limit the utilization of the other. Approximately 80 per cent of the phosphorus and 99 per cent of the calcium in the body is present in the bones and teeth. These figures indicate the importance of calcium and phosphorus in the ration and the role they play in giving rigidity and strength to the skeletal structure. Although the other minerals are contained in smaller amounts in the animal's body, their presence is just as important as that of calcium and phosphorus.

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usually no minerals other than a small amount of salt are needed. These protein supplements usually supply enough additional calcium and phosphorus to satisfy the needs of the pig. They may also supply enough additional copper and iron to sufficiently enrich swine rations.

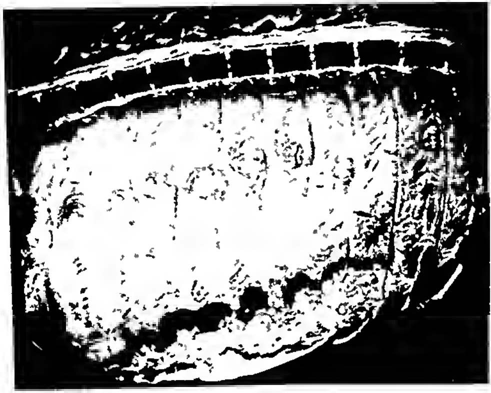

Fig 10 Beading of the ribs Large knobs develop at the juncture of the bony with the cartilaginous parts of the ribs This is caused by a calcium and phosphorus deficiency (Courtesy G. Bohstedt and Ohio and Wisconsin Agricultural Experiment Stations)

3.6c Minerals Needed When Plant Proteins Are Fed

When little or no animal protein supplement is fed, and the grain feeds are balanced with soybean oil meal, peanut meal, cottonseed meal, or other plant protein concentrates (all low in calcium, but good in phosphorus), it becomes necessary to feed a calcium supplement. If hog rations lack, in large part, only calcium, then it is not so economical to use only a single supplement—like bone meal, for example, that furnishes both calcium

Grains are fair sources of phosphorus and protein supplements are good sources; so a well-balanced ration usually contains almost enough—if not enough—phosphorus to supply the needs of the pig. Table XI shows the calcium and phosphorus

TABLE XI. Calcium and Phosphorus in Some Widely Used Feeds

Feeding stuff	Calcium, %	Phosphorus, %
Protein concentrates		
Wheat bran, 15% protein	0.10	1.20
Cottonseed meal, 41% protein	0.20	1.10
Skim milk, dried, 34% protein	*1.30*	*1.00*
Wheat standard middlings, 16% protein	0.10	0.80
Linseed meal, solvent, 36% protein	0.40	0.90
Soybean oil meal, solvent, 45% protein	0 25	0.60
Corn gluten feed, 22% protein	0.20	0.60
Fish meal, menhaden, 60% protein	5.00	3.25
Meat and bone scraps, 50% protein	10.00	4.80
Tankage, 60% protein	6.50	3.50
Grains		
Barley	0 08	0.30
Oats	0.10	0.35
Corn, yellow	0.02	0.25
Wheat, hard winter or spring	0.05	0.40
Roughage		
Alfalfa meal, 17% protein, dehydrated	1.60	0 20
Requirement of pig for calcium and phosphorus (6)	0.55–0 80	0.33–0.60

These data were compiled by C. W. Sievert and B W. Fairbanks. The author gratefully acknowledges their permission and that of the *Feed Bag Red Book 1955* for reproducing these data.

content of some feeds which are widely used (see Table XX for the calcium and phosphorus level of feeds).

3.6b Minerals Needed When Animal Proteins Are Fed

If the protein supplement in swine rations is made up largely of fish meal, tankage, meat and bone scraps, or milk by-products,

TABLE XII Calcium and Phosphorus in Mineral Supplements* (19)

Mineral supplement	Calcium %	Phosphorus %
Bone meal steamed	30.0	13.9
Defluorinated superphosphate	28.3	12.3
Defluorinated phosphate rock a*	21.0	9.0
Defluorinated phosphate rock b*	29.0	13.0
Dicalcium phosphate	26.5	20.5
Monocalcium phosphate	16.0	24.0
Spent bone black	22.0	13.1
Monosodium phosphate	—	22.4
Disodium phosphate	—	8.6
Limestone	38.3	—
Oyster shell flour	36.9	—

* Because of the limited number of products on the market figures are given for two types of defluorinated rock that are being produced for livestock feeding.

3.6f Absorption of Calcium and Phosphorus

A large excess of either calcium or phosphorus interferes with the absorption of the other. With an excess of either one, the other tends to become tied up as the insoluble tricalcium phosphate, which the pig cannot absorb. This explains why it is important to have a suitable ratio between calcium and phosphorus for if one mineral is too high in relation to the other, it accentuates the lack of the mineral which is low. Thus, if a swine producer using a ration low in phosphorus were to include a very high level of calcium in the ration, the phosphorus level would become even lower.

Large amounts of iron, magnesium, and aluminum in the ration should be avoided, since they interfere with the absorption of phosphorus by forming insoluble phosphates.

3.6g Availability of Phytin Phosphorus

About half or more of the phosphorus in cereal grains is in the form of phytin. Phytin consists of the vitamin inositol combined with phosphorus and other minerals. Studies at Wiscon-

and phosphorus—because bone meal costs more than ground limestone, oyster shell flour, and other mineral supplements that supply only calcium. Adding 0.5 to 1.0 per cent of limestone (or some other calcium supplement) plus 0.5 per cent bone meal (or some other calcium and phosphorus supplement) will usually supply the extra needed calcium and phosphorus for rations balanced, in large part, with plant protein concentrates. Bone meal is not needed if enough phosphorus is already contained in the ration.

3.6d The Calcium-Phosphorus Ratio and Vitamin D

To obtain proper calcium and phosphorus use, three requirements must be met. First, a sufficient supply of calcium and phosphorus must be fed; second, a suitable ratio between them must be maintained; and third, a sufficient amount of vitamin D must be included. The proper calcium-phosphorus ratio is approximately 1.5:1.0. It will vary above or below 1.5 depending on the weight and age of the pig. However, if the pig gets plenty of vitamin D, the ratio of calcium to phosphorus becomes a little less important, as he makes more efficient use of the calcium and phosphorus in the ration. A deficiency of vitamin D causes decreased use of calcium and phosphorus, even though other factors are optimum. Vitamin D is, therefore, a vital factor in the absorption and utilization of calcium and phosphorus by the body.

Sunlight and good-quality sun-cured hays are the major sources of vitamin D under farm conditions.

3.6e Sources of Calcium and Phosphorus

Table XII lists sources of calcium and phosphorus and their approximate percentage in various mineral supplements. The composition of these mineral supplements varies somewhat depending on the purity of the raw material and the method used in processing.

showed that the growing-fattening pig did not utilize plant phosphorus as efficiently as inorganic phosphorus, as evidenced by poorer feed efficiency and decreased rate of gain. More studies are needed to clarify the extent of phytin phosphorus use by the pig.

3.6h Requirements of the Pig for Calcium and Phosphorus

Table XIII shows the calcium and phosphorus levels recommended for swine by the National Research Council Committee on Swine Nutrient Requirements (6).

Table XIII Calcium and Phosphorus Requirements of Pig as Recommended by the National Research Council (6)

	Weight of pig, lb	Calcium, % in ration	Phosphorus, % in ration	Calcium to phosphorus ratio
Market stock	25	0.8	0.60	1.33:1.0
Market stock	50	0.65	0.45	1.44:1.0
Market stock	100	0.65	0.45	1.44:1.0
Market stock	150	0.55	0.33	1.67:1.0
Market stock	200	0.55	0.33	1.67:1.0
Market stock	250	0.55	0.33	1.67:1.0
Pregnant females and breeding boars				
Young stock	300	0.60	0.40	1.5:1.0
Adults	500	0.60	0.40	1.5:1.0
Lactating females				
Gilts	350	0.60	0.40	1.5:1.0
Adults	450	0.60	0.40	1.5:1.0

By studying the table it is apparent that the calcium and phosphorus requirement of the pig decreases with age; and that the young animal has the highest requirements.

A recent comprehensive study at the Iowa Station (14) showed that the calcium and phosphorus needed to insure optimum rate of gain and skeletal response appears to be 0.8 and 0.6 per cent, respectively, for pigs from 25 pounds to 100 pounds live weight,

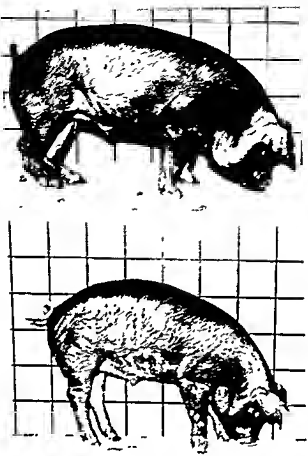

Fig. 11. Phosphorus deficiency. Note abnormal bone formation. This pig was fed from weaning on low phosphorus ration containing 0.18 per cent phosphorus. The bottom pig was fed same ration except it contained 0.55 per cent phosphorus. (Courtesy W. M. Beeson, Purdue Agricultural Experiment Station.)

sin (25) showed that phytin phosphorus could be utilized by the pig. *It has been shown that a liberal supply of vitamin D is* important in the utilization of phytin phosphorus. In a recent study at Purdue (41) where radioactive calcium phytate was used, it was found that the phytin phosphorus was poorly utilized by the weanling pig. Only 1.95 per cent of the inorganic (PO_4) phosphorus was excreted by the pig, as compared to 61.2 per cent of the calcium phytate phosphorus. Iowa workers (13) also

Besides feeding calcium and phosphorus in the ration, it is wise to supply these two minerals in a mineral box. In many

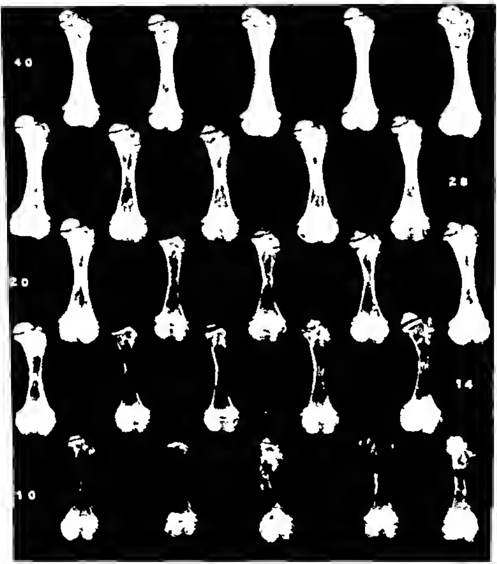

Fig. 13. X-ray reproductions of the left femur of pigs 35 days of age which received various levels of phosphorus for a 28-day period The number at the end of the row represents the level of phosphorus (0 10, 0 14, 0 20, 0 28, and 0.40 per cent) in the ration. Note the increased density as the level of phosphorus in the ration increased. (Courtesy G E Combs and D. V. Caron, Iowa Agricultural Experiment Station.)

cases, the farmer may not feed enough of a mixed ration to supply the total needs of the pig. Thus, even though the ration itself is adequate in calcium and phosphorus, the pig will not

and 0.7 and 0.5 per cent, respectively, for pigs from 25 pounds to 200 pounds live weight. These levels are slightly higher than those recommended by the National Research Council (Table XIII). This indicates, that with properly fortified rations, a higher level of calcium and phosphorus may be needed by the pig for optimum growth. There is a lack of recent information on

Fig 12. Calcium deficiency obtained after 12 weeks on ration containing 0 25 per cent calcium. Note the paralyzed hindquarters (*Courtesy C. E. Aubel and J. S. Hughes, Kansas Agricultural Experiment Station.*)

the calcium and phosphorus requirements of the pig. There is a need for more studies to determine these requirements at various stages of the life cycle of the pig using highly fortified rations such as are now being fed.

A good pasture, if lush and palatable, should reduce the amount of calcium needed in the concentrate ration. Pigs or sows eating pasture as a large part of their ration can get by with less calcium in the concentrate feed.

Deficient pigs have been shown to keep licking all parts of their cages for salt. An example of the value of salt in the ration was shown in a Purdue experiment (4). Pigs receiving no salt in their rations required 174 pounds more feed per hundred pounds of gain and their rate of gain was only half as fast as that of pigs given adequate salt. One pound of salt, costing only one or two cents, saved 287 pounds of feed. This is a very striking example of the major importance of salt to the pig.

3.7b Methods of Feeding Salt

Salt may be included in the ration, or it may be provided in the form of loose salt or salt blocks. But it is rather difficult for pigs to secure enough salt from block salt. Finely ground salt is preferred for use in swine feeding.

3.7c Requirements of the Pig for Salt

The National Research Council Committee on Swine Nutrient Requirements (6) recommends a level of 0.5 per cent of salt in the ration for all ages and classes of swine (Table I). This level may be a little high for young pigs, since a recent Wisconsin experiment (37) showed that a lower level of salt is sufficient. For optimum growth, they found that the pig should receive approximately 36 to 42 mg. of sodium per kilogram live weight daily. *This amounts to 0.08 to 0.10 per cent of the feed consumed.* The ration should also supply 53 to 64 mg. of chlorine daily per kilogram of body weight. A level of 0.12 to 0.13 per cent chlorine in the ration would satisfy this requirement. Combining both, 0.20 to 0.23 per cent salt in the ration would satisfy the requirements of the growing pig according to the Wisconsin workers (37). However, there is no harm in a little excess salt.

Since salt increases the palatability of the ration, it is a good practice to include salt in the mixed ration. It should also be self-fed in a mineral box in case the pig, for some reason, needs more than is included in the ration. Moreover, in some cases farmers may not feed enough of the mixed ration to supply

get enough of these two minerals unless he gets enough of the mixed ration. It is good insurance to supply calcium and phosphorus in a mineral box so that the pig can eat more of these minerals if he needs them.

Many commercial mineral mixtures on the market can be used. Following are some mineral mixtures which can be mixed by the farmer in case he wishes to mix his own.

Plan I—Self-Feeding. Use a three-compartment mineral box with limestone (or other calcium supplement) in one compartment, bone meal in the second, and trace mineralized salt in the third compartment. (Note: Pigs can halance their own mineral needs by eating what they need from each compartment.)

Plan II—Mixtures.

	I	II	III
Limestone (or other calcium supplement)	250 lb.	200	200
Bone meal (or other calcium and phosphorus supplement)	100 lb.	150	200
Salt—trace mineralized	150 lb.	150	100

(*Note:* A mixture can be used when you do not have or do not wish to use a 3-compartment mineral box. Offer one of these mixtures free-choice in a mineral box.)

3.7 SALT

Salt contains both sodium and chlorine. These minerals occur almost entirely in the fluids and soft tissues of the body, where they play very important roles. Milk contains a considerable amount of sodium and chlorine, and a lack of salt in the ration will ultimately decrease milk production. Salt serves both as a condiment and a nutrient. As a condiment it stimulates saliva secretion and promotes the action of certain enzymes. Without salt, feed is less palatable to the animal and is less efficiently used.

3.7a Value of Salt in Ration

Sodium, chlorine, and sodium chloride deficiencies in the pig cause a decrease in daily gain and efficiency of feed utilization.

body and iodine is necessary for thyroxine production. If an animal does not obtain enough iodine in the ration, the thyroid gland in the neck will enlarge in an attempt to make more thyroxine; then simple goiter develops (3,11). In farm animals, goiters are usually found in the young at birth; this is a result of a deficiency of iodine in the ration of the mother during the gestation period. Such young animals are usually born weak or dead. Older farm animals rarely show any symptoms of a lack of iodine.

Iodine deficiencies occur in certain areas of the world where soil and water are deficient in iodine. In the United States, the main iodine-deficient areas are in the Great Lakes region and westward toward the Pacific Coast. However, it is possible that other borderline iodine-deficient areas may exist in the United States.

3.8a Effect of Deficiency in the Pig

A sow which lacks iodine in her ration will give birth to "hairless pigs." These pigs are bloated and have thick skins and puffy necks. Some of them are born dead; others are born alive, but weak (26). Thus, an iodine deficiency causes severe losses in pigs.

3.8b Iodine Requirements of the Pig

There is very little information available on the iodine requirements of the pig. The National Research Council Committee on Nutrient Requirements for Swine (6) recommends 0.2 mg. of iodine per 100 pounds of body weight for pregnant sows. They also state that the iodine requirement is somewhat less for growing swine. Excessive amounts of iodine should not be given because of the danger of overdosage. An example of such a danger is the fact that overdosage of iodine depressed weight and caused irregularities of reproduction in ewes.

The best way to supply iodine is through the use of iodized salt. The iodine in the salt should be stabilized; this protects the iodine from being destroyed. Stabilization of iodine in salt is

the pigs' need for salt. It will pay to have salt always available for pigs in case they need it. A mineral box full of salt is good, cheap insurance against a deficiency of this mineral.

3.8 IODINE

Pigs require iodine for growth, reproduction, and lactation. The hormone thyroxine controls the rate of metabolism in the

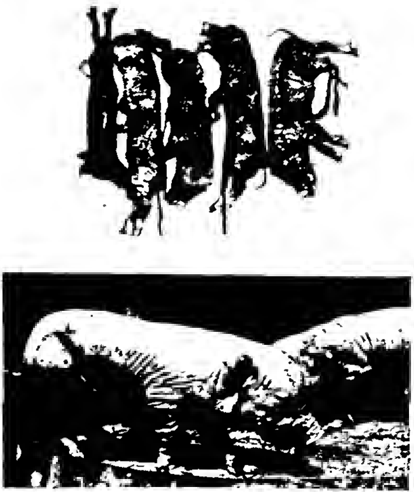

Fig. 14. Iodine deficiency. The top photo shows a litter of hairless pigs which were stillborn The other shows a live hairless pig (Courtesy J. W. Kalkus, Western Washington Experiment Station.)

0.1 mg. of iodine per pound of total ration as a satisfactory level to use. This should permit normal growth and reproduction.

3.9 IRON AND COPPER

Both iron and copper play an important part in hemoglobin formation. They are thus essential in preventing nutritional anemia (10,12). Copper is not contained in hemoglobin, but a trace of it is necessary before the body can utilize iron for hemoglobin formation (52). Both iron and copper are also constituents of different enzymes. Thus, iron and copper are very important, and affect every organ and tissue of the body.

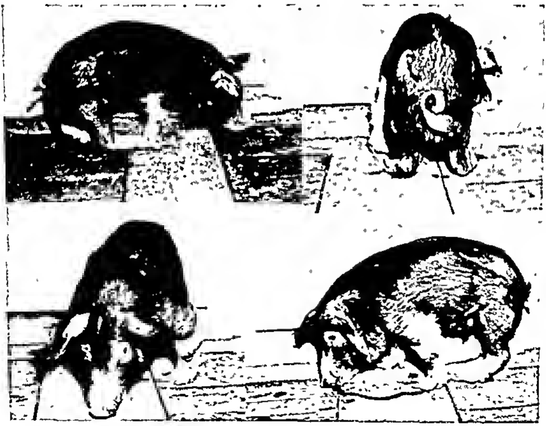

Fig. 16. Note skeletal deformities due to copper deficiency in the pig. Both hind and fore legs have been affected severely. (Courtesy G. E. Cartwright and M. M. Wintrobe, University of Utah, and with permission of *Blood VII*, figure 1, page 1058 (1952).)

usually brought about by adding a reducing agent called sodium thiosulfate (frequently referred to as hyposulfite of soda or "hypo"), which protects the iodine. When potassium iodine (KI) is added to salt without a stabilizer, a large percentage of the iodine may be lost when the salt is allowed to stand for a long time before it is eaten. The iodine needs of the pig should be met by using stabilized iodized salt containing 0.007 per cent iodine in the ration at a level of 0.5 per cent and/or fed free-choice. The National Research Council Committee on Nutrient Requirements for Swine (6) has made a tentative recommendation of

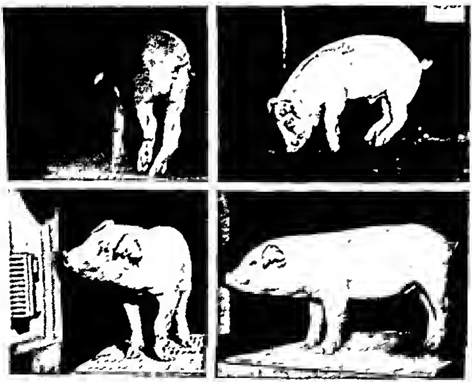

Fig. 15. Copper deficiency. Note the drawing under of the rear legs and crookedness of the forelegs, the swelling in the region of the hocks, and a turning of the rear leg, and the extreme weakness of the carpal joints in the foreleg. The normal appearing pig in lower right of photo was fed 2 mg. of copper per day. (Courtesy H. S. Teague, L. E. Carpenter, and Hormel Institute and *Journal of Nutrition*.)

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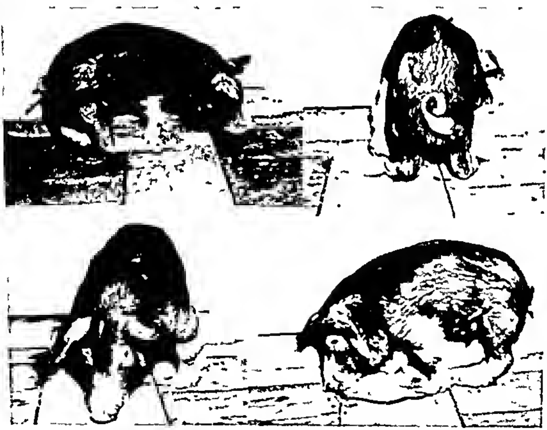

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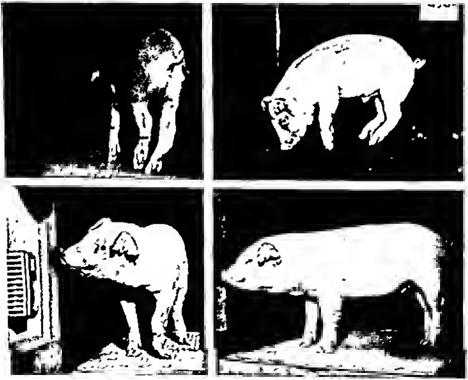

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kept away from dirt, they will usually develop anemia or "thumps," and they may die by the time they are 4 to 6 weeks of age If the pigs have access to dirt, they usually begin to eat a little of it a few days after birth Thus they obtain the small amounts of iron and copper needed to prevent anemia In fact, many farmers put some fresh sod or soil into the pen each day as a means of preventing anemia However, in doing so, one should take the precaution of getting soil or sod from a spot where pigs have not been kept for at least a year This will guard against the pigs getting eggs of roundworms or other parasites from infested soil

Anemic pigs lack a healthy pink color and their blood looks watery They lack appetite and become weak and inactive In severe cases, the pig's breathing becomes heavy or labored, this is commonly described as "thumps" The pig breathes heavily in an effort to get enough oxygen to the various tissues of the body This is brought about by the lack of hemoglobin (which carries oxygen from lungs to all parts of the body) The pig tries to make up for this lack by breathing harder to make the available hemoglobin carry as much oxygen as possible through its body If the pig survives for 5 or 6 weeks, it will usually recover, since by that time it is eating some of the sow's feed, which contains copper and iron However, pigs that have had anemia may not do too well in the future and some may turn out to be runts

3 9c Preventing Anemia in Suckling Pigs

Anemia can be prevented by swabbing the sow's udder with copperas (ferrous sulfate) or another soluble iron salt until the pigs are 4 to 6 weeks old (20) To make copperas solution, dissolve 1 pound of ferrous sulfate in a quart of hot water. Put this solution on the udder with a clean paint brush, or by a swab made by tying a piece of cloth to a stick Copperas contains enough copper as an impurity to supply the needs of the pig Another way to prevent anemia is to give pigs a dose of iron solution or an iron pill by mouth once a week Using pre-

3.9a Copper Deficiency in Young Pigs

The Hormel Institute (45) produced a copper deficiency in pigs on a raw whole milk diet. Besides anemia, an unusual leg condition developed. The animals lacked rigidity in the leg joints. The hocks became exeessively flexed and this forced the animal to a sitting position. The forelegs showed various types and degrees of crookedness. In the extreme state, the animals lost the use of the forelegs and, although not paralyzed, they remained in a prone position. In some cases, the administration of copper completely cured the symptoms (Fig. 15).

3.9b Iron and Copper Deficiency in Suckling Pigs

Milk is very low in iron and copper. Feeding iron and/or copper to pregnant or lactating sows has not been effective in pre-

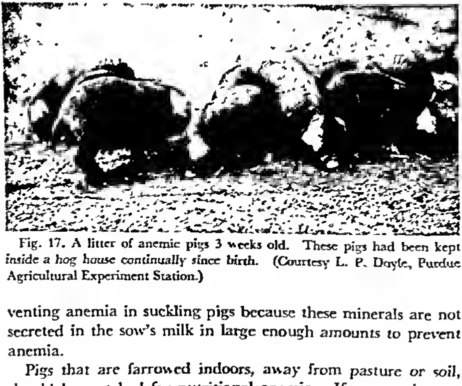

Fig. 17. A litter of anemic pigs 3 weeks old. These pigs had been kept inside a hog house continually since birth. (Courtesy L. P. Doyle, Purdue Agricultural Experiment Station.)

venting anemia in suckling pigs because these minerals are not secreted in the sow's milk in large enough amounts to prevent anemia.

Pigs that are farrowed indoors, away from pasture or soil, should be watched for nutritional anemia. If young pigs are

cent white fish meal One ounce of cod-liver oil was fed each pig once weekly Whether this beneficial effect from copper is in some way related to the type of ration used remains to be determined Studies under way in this country will determine whether high levels of copper will benefit pigs fed the kind of rations used here This report is very interesting and needs follow-up study to determine its implication in swine feeding A recent Florida study (50) showed no beneficial effect from adding 250 p p m of copper sulfate to a corn soybean oil meal ration In fact the pigs fed this high level of copper performed more poorly than the control animals

3 10 COBALT

Cobalt is a constituent of vitamin B_{1}. Recently it has been shown that the cobalt fed to sheep is used by the microorganisms in the rumen to make vitamin B_{12} The need for cobalt by the pig has not been definitely established Several workers (32, 40,44,51) have reported that the addition of cobalt to practical swine rations increased the rate of growth and efficiency of feed utilization North Dakota workers (16) obtained a good growth response from pigs fed added cobalt carbonate at a level of 885 mg of cobalt per pound of ration However, it is doubtful if cobalt benefits growth if the ration contains adequate amounts of vitamin B_{12} (31) This point needs further study before cobalt requirements for the pig can be determined

3 11 MANGANESE

Manganese has several important functions in the body, thus it is important to feed rations adequate in it Pigs definitely need manganese in their rations, but published data are not in agreement as to how much Early work at Arkansas showed that pigs made good growth on a ration containing less than 1/[illegible] p p m of manganese (22,23), and reproduction was satisfactory when the manganese was increased to 6 p p m (23) More recent work at Wisconsin, however, has shown that

starter and starter feeds should also prevent anemia, since they are fortified with iron and copper.

3.9d Excess Iron and Copper

Excess iron and copper may be harmful to swine. Excess iron interferes with phosphorus absorption by forming insoluble iron phosphates. Excess levels of copper are toxic to the pig. If a high enough level is fed it will cause death.

3.9e Requirements of Copper and Iron

Ten to fifteen milligrams of iron daily for the first 6 weeks after birth has been found adequate to maintain normal hemoglobin levels in suckling pigs (6). After the suckling period, pigs usually get enough copper and iron in their normal rations. But possibly in a few areas, where the soil may be deficient in these two mineral elements, diets may be deficient. With the exception of milk, most of the feeds for swine contain liberal amounts of iron in relation to the needs of the body.

Although the exact requirement for copper is not known, feeding 2 mg. of copper daily to pigs on a raw whole milk diet has prevented copper-deficiency symptoms (45). A copper deficiency was produced by restricting 5- to 6-day-old pigs for 6 weeks to a copper intake of 0.035 mg. per pound of body weight (45). The amount of copper required is very small and is usually about one-tenth of the iron requirement. The National Research Council Committee on Swine Nutrient Requirements (6) has made a tentative recommendation of 15 mg. of iron and 2 mg. of copper per pound of total ration as a level that will permit normal growth and reproduction.

A recent report from England (5) shows that rate of gain rose when copper sulfate was added at a high level of 0.1 per cent of the diet (approximately 250 p.p.m. of copper). These results were unexpected since normal fattening rations for pigs usually contain 5 to 10 p.p.m. of copper. They used a ration of 50 per cent barley meal, 40 per cent fine wheat offal, and 10 per

growth and efficiency of feed utilization was improved by increasing the level of manganese in the ration from 12 to 40 p p m (18) Increasing the level of manganese above 40 p p m did not improve performance

No significant benefits in reproduction and lactation were obtained from adding manganese to a ration containing 12 p p m (18) However, sows fed 40 p p m of manganese showed a trend toward slightly better performance

It is evident that the exact manganese requirements of the pig have not been definitely determined Evidently, the ash content of the ration influences the manganese requirement of the pig Arkansas (24) and Pennsylvania (29) data indicate that more manganese is needed with higher levels of ash in the ration

Excess manganese is harmful, as was shown by Wisconsin workers (18) A level of 500 p p m of manganese retarded appetite and growth, especially during the later part of the trial The pigs showed stiffness of limbs and stilted gait toward the end of the experiment

The National Research Council Committee on Swine Nutrient Requirements (6) has tentatively recommended 18 0 mg of manganese per pound of total ration as adequate to permit normal growth and reproduction

3 12 POTASSIUM

Potassium plays some very important roles in the body, thus it is necessary that rations be adequate in this mineral However, the usual feeds used in swine rations contain adequate amounts of potassium to meet the needs of the pig A deficiency of potassium has not been observed in pigs under practical farm conditions

Recent work at Wisconsin (37) showed that pigs should receive a ration containing 100 to 120 mg of potassium per kilo gram body weight per day This amounts to 0 23 to 0 28 per cent of the ration The average daily intake of potassium in

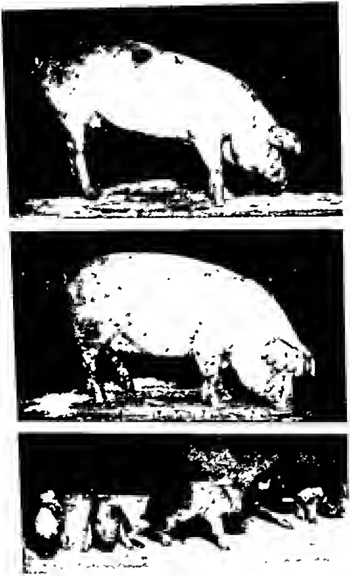

Fig. 18. Manganese deficiency. Top photo shows 132-day-old gilt fed 40 p p.m. manganese since she weighed 8.5 pounds. Middle photo shows a littermate gilt started at same weight and 132 days old fed 0.5 p.p.m. of manganese. Note increased fat deposition due to low manganese diet. Lower photo shows a litter from sow fed 0.5 p p m. of manganese. The pigs showed weakness and poor sense of balance at birth. (Courtesy W. M. Beeson, Purdue Agricultural Experiment Station.)

3.13 MAGNESIUM

Magnesium is closely associated with calcium and phosphorus. It is an essential constituent of bones and teeth and is required in many other body functions. No information is available on the requirements for magnesium by the pig. Most feeds contain the small amounts of magnesium needed by animals. Thus, as far as is known, there is no need to add magnesium to practical swine rations.

Formerly it was thought that an excess of magnesium would cause a large loss of calcium. Recently, however, it has been found that unless the excess of magnesium is very large, no harmful effects occur, provided the ration contains an ample supply of calcium and phosphorus. Thus, a small excess of magnesium will not disturb calcium retention, though it may tend to increase the requirements for calcium and phosphorus by the pig. Proof of this is the fact that dolomitic limestone is a satisfactory source of calcium for bone formation despite its magnesium content and is used widely in swine rations (9).

3.14 ZINC

Zinc is very widely distributed throughout the body and plays an essential role in body processes. Zinc is also widely distributed in feeds, and until recently it was thought that no attention need be given to adding it to swine rations. However, Alabama workers recently published a paper (48) showing that "swine dermatitis" or "parakeratosis" could be cured or prevented by zinc. An apparently similar dermatitis has been observed by many workers in different areas of the United States for the last 10 to 15 years (30,48). But no one suspected zinc might be involved in this mangelike condition. Parakeratosis evidently is aggravated by high levels of calcium and/or phosphorus. For example, the Alabama workers produced no parakeratosis with their ration until they added higher levels of calcium and/or phosphorus to their control diet. This, in some way

their experiments amounted to 5.15 grams per 100 pounds of live weight. This figure is about double that obtained in 1942 by California workers (21); their figure was 2.36 grams.

TABLE XIV. Potassium Content of Some Feeds (27)

	Per cent of potassium
Corn	0.34 (0.27–0.45)[a]
Barley	0.47 (0.33–0.54)
Wheat	0.34 (0.18–0.45)
Oats	0.51 (0.40–0.69)
Soybean oil meal, exp. proc.	1.98 (1.75–2.37)
Cottonseed meal	1.26 (1.15–1.35)
Fish meal	0.79 (0.57–0.97)
Tankage, 60% grade	0.51 (0.42–0.56)
Alfalfa meal, dehydrated	2.20 (1.86–2.68)
Swine requirement for growth (26)	0.23–0.28

[a] Lowest and highest value.

As far as can be ascertained, the pigs in the California experiment gained at one-half the rate of the pigs in the Wisconsin trial. It is possible that the decrease in rate of gain caused a lower requirement for potassium in the pigs in the California study.

There is still some question concerning the old theory that an excess of potassium causes the animal to excrete more sodium, and this in turn increases the need for more salt. Present opinion indicates that a high potassium intake may result in an increased sodium excretion by the body, but some adjustment occurs rapidly wherehy this increased loss is stopped.

A quick look at a few representative feeds in Table XIV show that feeds used in swine rations contain adequate potassium and it is not necessary to add potassium to practical rations for growing pigs. No information is available on potassium requirements for reproducing and lactating sows. But since feeds contain more than is needed for growth, it is likely they also contain enough for reproduction and lactation.

increased almost immediately, and their improvement in weight gains and skin condition was obvious in 1 week These animals soon apparently completely recovered from the skin lesions and associated symptoms The parakeratosis was produced in pigs on a ration containing 34 to 44 p p m of zinc Supplementing the diet with 0 02 per cent (104 p p m) zinc carbonate (or 0 01 per cent zinc carbonate as part of a trace mineral mixture) cured or prevented the dermatitis

Whether all cases of dermatitis which have been observed by many workers are due to a zinc deficiency remains to be determined However, at least one kind of dermatitis has responded to zinc supplementation It is very possible that most of the dermatitis which has been observed throughout the country is due to a zinc deficiency In the near future, the answer to this question will be determined, as various experiment stations try zinc on the dermatitis observed in their pigs

Recently, Wisconsin (34) and Michigan workers (36) have produced parakeratosis in the pig by feeding high levels of calcium in the ration Their results indicate that high calcium in the ration is at least one of the predisposing factors in parakeratosis and that zinc will prevent the occurrence of the disease The level of calcium, and possibly other factors, in the ration determines how much zinc is needed to prevent the parakeratosis Levels of 50 to slightly over 100 p p m of zinc have been used in preventing the disease (34,36,48) Until more research information is obtained, it would appear that rations should contain levels of 50 to slightly over 100 p p m of zinc to prevent parakeratosis Supplementing diets with 100 p p m of zinc requires 0 02 per cent zinc carbonate or 0 4 pound per ton of feed Future studies will determine the proper level of zinc to use as well as the more precise cause for parakeratosis

Many workers had not tried zinc recently because of early work (in 1937) in New Zealand (17) This showed that feeding 0 1 per cent zinc, in the form of zinc lactate, resulted in lameness, unthriftiness, and arthritis in weanling pigs This finding was confirmed in 1942 by Illinois workers (42) However, they

yet undetermined, resulted in a higher requirement for zinc and thus parakeratosis developed.

Fig. 19. Top photo shows a pig with a typical case of parakeratosis. Note same pig in lower photo 41 days later after zinc was added to the ration. Improvement was noted within a week after zinc was added. (Courtesy L. E. Hanson, Minnesota Agricultural Experiment Station.)

The Alabama group (48) found that pigs responded to the addition of zinc promptly and dramatically. Their appetite

organic forms. The pig has little, if any, ability to use the inorganic forms of sulfur. Thus, adding free sulfur in mineral mixtures for swine as a source of sulfur is not recommended. This means that sulfur is an essential mineral element only in a special way. It needs to be supplied as a constituent of organic compounds rather than as a mineral salt. Thus, no attention needs to be paid to adding an inorganic source of sulfur to swine rations. Meeting the needs of the pig for sulfur-containing amino acids and vitamins will be discussed in the chapters on proteins and vitamins.

3.16 TOXIC MINERALS

Occasionally fluorine, selenium, and molybdenum may be contained in feeds at levels which may be harmful to animals. The following discussion deals with the problem as it applies to swine.

3.16a Fluorine

Fluorine in excess is a poison; it is also cumulative. If given for a short time only it accumulates in the bones and teeth without evident harm. This is fortunate, because it protects the animal for a long time. However, after the bones become saturated with fluorine, the fluorine consumed starts producing its poisonous effect in the body. This means one may feed a high-fluorine mineral for a long time without realizing that the animal is accumulating it, but eventually the animal will be affected severely. For example, in one Wisconsin experiment, it took three years before a borderline intake of fluorine affected reproduction in dairy cows. Thus, short feeding trials are not reliable sources of information on possible fluorine toxicity.

Fluorine becomes a hazard in swine feeding when rock phosphates, acid or superphosphates manufactured from them, or phosphatic limestones are used. Phosphate rock usually contains from 3.5 to 4.0 per cent of fluorine. Fortunately, ordinary feeds do not contain harmful amounts of fluorine, even

also found that pigs weighing 75 to 100 pounds when started on experiment did not produce the symptoms; whereas 9- to 13-pound pigs did. This may be due to the more advanced stage of bone development in the larger pigs or to a higher zinc intake per kilogram of body weight by the smaller pigs. At any rate, this information indicates that considerably more work needs to be done on the zinc requirements and levels to be used in swine feeding.

Table XV gives data on the zinc content of some commonly used feeds. These data are from the Michigan Station and were obtained on single samples. Thus they do not indicate the variation which might occur in different samples of the same feedstuff. They are presented, however, because there is little or no other information available on the zinc content of commonly used swine feed ingredients.

TABLE XV. Zinc Content of Some Commonly Used Feed Ingredients[a]

Feed ingredient	Zinc, p p m
Soybean oil meal (solvent)	77.3
Cottonseed oil meal (expeller)	66.1
Cottonseed oil meal (solvent)	63.4
Meat and bone scrap	131.4
Fish meal (menhaden)	63.9
Alfalfa meal (dehydrated)	31.7
Corn	31.2
Oats	33.5
Bone meal	146.1
Limestone (38% Ca)	4.5
Dicalcium phosphate (26% Ca & 21% P)	0.0

[a] Determined by R. W. Luecke, Michigan State University in 1956.

3.15 SULFUR

Sulfur is very important since it plays an essential role in many body functions. It occurs in the body mostly in the form of the sulfur-containing amino acids cystine and methionine. It is also present in insulin and in the vitamins thiamine and biotin. Sulfur is present in the body almost entirely in such

per cent arsanilic acid and 0 005 per cent 3-nitro-4-hydroxyphenyl-arsonic acid in the ration counteracted the effects of selenium poisoning (up to 10 p p m of selenite selenium in the ration) However, care must be used with arsenic compounds, since they are also toxic if taken in excess

3 16c Molybdenum

Excess molybdenum in the soil occurs in certain areas of the world In the United States it has been reported in California and Florida Excess molybdenum in the forage affects ruminants The use of copper sulfate counteracts most, if not all, the harmful effects of the excess molybdenum in the forage for cattle However, this condition is more complex than a simple copper-molybdenum relationship Studies at the Florida Station (33) have shown that the pig is not affected by excess molybdenum at the levels usually found in feeds It was also found that little or no molybdenum is transferred from the sow to the developing fetuses (43) Evidently, the placenta serves as a barrier preventing molybdenum transfer from the sow to the developing young As far as is known, excess molybdenum is not a problem in practical swine rations

3 17 THE VALUE OF CHARCOAL

Occasionally, some farmers feed only charcoal to their animals as a source of minerals Most of the experiments which have been conducted show that adding charcoal to the ration is usually not beneficial (46,47) Thus, swine producers should not depend on charcoal as a source of minerals for balancing rations

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though they have been grown on soils fertilized with rock phosphate or superphosphate for years.

Using rock phosphate, or compounds made from it, from which the fluorine has not been removed causes the following symptoms (27,28) in animals: pitting, erosion, and wearing down of the teeth; softening and overgrowth of the bones; loss of appetite; poor gains, harmful changes in the kidneys, and, finally, death. In severe cases where the teeth wear down, the animals have difficulty chewing feed. Sometimes, the pulp cavities become exposed. This causes animals to be reluctant to drink cool water because it pains them to do so.

H. H. Mitchell of Illinois (39) in a National Research Council Publication recommends the following:

1. The fluorine content of any minerals or mineral mixtures which are to be used directly for the feed of swine should not exceed 0.45 per cent.

2. The permissible level of fluorine in the total dry feed of swine is tentatively set at 0.003 per cent.

These figures should be used as a guide in determining the amount of fluorine to use in swine rations.

3.16b Selenium

This element occurs in excess in certain areas of the United States and the world. In the United States, *it is found* in South Dakota, Wyoming, Montana, and possibly other states. Selenium toxicity is known as "alkali disease" and "blind staggers." It causes a loss of hair, sloughing of the hoofs, lameness, decreased feed intake, and, eventually, death from starvation. Any soil which contains more than 0.5 p.p.m. of selenium is potentially dangerous. Both grains and forages take up toxic levels of selenium. Chronic toxicity is caused in rations as low as 8.5 p.p.m. of selenium. Young animals are the most susceptible. If the level of selenium is too low to cause other symptoms, it will cause retarded growth. Small amounts of certain arsenic compounds largely counteract the harmful effects of selenium. South Dakota workers (49) found that 0.02

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CHAPTER IV

Vitamin Requirements of the Pig

4.0 INTRODUCTION

Most swine producers have no doubt heard the word vitamin at some time or another. To many of them, it is some mysterious substance which they think is beyond them to do anything about. Research at various experiment stations, however, has shown that a farmer can, by following sound feeding practices, prevent vitamin deficiencies which cost him many hard-earned dollars.

Most of the work on vitamins has been conducted since 1911, when the term vitamine was coined by Casimir Funk (55). At that time Funk was working at the Lister Institute in London. Later the letter *e* was dropped, and the present term "vitamin" adopted.

Vitamins are organic compounds which perform many essential functions in the body and are needed in only very small amounts. They are not related to each other like proteins, carbohydrates, and fats. All are different in structure and also perform different functions. Thus, it is very important that all vitamins be supplied in adequate amounts in swine rations.

Pigs synthesize some of the vitamins in large enough quantities to supply their daily needs. Most of them, however, must be supplied in the diet, since the pig does not synthesize them or does not synthesize them in large enough amounts to supply its needs. Below is a list of the known vitamins. It must be stated, though, that there are still some unknown vitamins.

suckled the sow for a considerable length of time In most cases, the information was gained with weanling pigs or animals which weighed 30 to 50 pounds (after a critical stage in growth has been passed) when started on experiment A very challenging and interesting field lies barely untouched in determining the vitamin needs of the pig immediately after birth, before the pig has nursed Using such pigs, investigators can determine vitamin and other nutrient needs before the pig has obtained storage of many vital factors from the mother's milk Studies such as these, which also take into account the nutrition of the mother sow during gestation, and even during her growing and developing period, will show the function which vitamins and other nutrients fulfill in preventing small pig losses that occur, to a large extent, during the first few days after birth In other words, too much of our research work has been on a "piece meal" basis We need long-term studies which consider the whole life cycle of the pig and which delve into the interrelationships and effects of the various stages on the whole of swine nutrition

Some vitamins were studied years ago when some of the newer vitamins were not included in the ration It is possible that many vitamin deficiency syndromes which have been worked out were complicated by the lack of some of the newer vitamins not then known Moreover, many of the vitamins should be restudied with pigs on rations containing antibiotics to determine the effect these chemicals may have on vitamin needs For example, the Iowa Station has shown that one of the antibiotics appears to spare both B_{12} and pantothenic acid (27)

4 3 BORDERLINE DEFICIENCY MAY EXIST

A borderline deficiency of any vitamin may exist without the pig showing any of the known symptoms for each individual vitamin deficiency In that case, poor gains and expensive gains will be made by the pig In other words, the fact that the pig does not show any deficiency symptoms is no excuse for feeding a poor ration Borderline deficiencies in swine rations are

4.1 LIST OF VITAMINS

Water-Soluble Vitamins
- Vitamin C
- B-Complex Vitamins
  - Thiamine
  - Riboflavin
  - Niacin
  - Pantothenic acid
  - B_6
  - Choline
  - Inositol
  - Biotin
  - Pteroylglutamic acid
  - *p*-Aminobenzoic acid
  - B_{12}
  - B_{13}

Fat-Soluble Vitamins
- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

The advancement and accomplishments in the vitamin field during the last 15 years have been tremendous. It is well recognized now that vitamins are as important as protein, minerals, and other nutrients in the ration. We know that unless a feed contains the proper amount and balance of the various necessary vitamins, it is nutritionally inadequate. Naturally, livestock men, research workers, the feed manufacturer, and many others are vitally concerned with the role vitamins play in making rations more nutritionally adequate and thus more efficient and economical to the livestock producer.

4.2 WHAT IS KNOWN AND NOT KNOWN

In spite of the tremendous amount of information available on vitamins, present knowledge of the vitamin requirements of the pig for growth, reproduction, and lactation is still very inadequate. Although there is considerable information available on the vitamin requirements of the pig during growth, the surface of information concerning the vitamin needs of the sow during gestation and lactation has barely been scratched.

The information available on the vitamin needs of the pig during growth has been obtained mostly with pigs which have

oats, soybean oil meal, meat scraps, alfalfa meal, and mineral ration for young pigs Their ration supposedly contained enough of the three B-vitamins for normal growth when based on the recommendations of the National Research Council (7) However, their results showed the ration to be deficient in niacin, pantothenic acid, and riboflavin This is a good example to show that the results obtained with purified rations need to be verified also with natural rations

4 6 VITAMINS NEEDED FOR GROWTH

The young, growing-fattening pig has been shown to need the following vitamins in the ration A, D, thiamine, riboflavin, niacin, B_6, pantothenic acid, choline, pteroylglutamic acid, B_{12}, and B_{13} So far, most research workers agree that vitamins K, E, C, biotin, inositol, and para-aminobenzoic acid do not need to be added to swine rations Studies at Washington State (37) showed that adding vitamin E to natural and purified rations was of no benefit for growth Vitamin E, in so far as is known, is present in high enough amounts in natural rations to supply the needs for the pig Vitamins C, K, and biotin are usually synthesized, in so far as is known, in high enough amounts by the pig to supply its needs *Para*-aminobenzoic acid and inositol have not been of any benefit for growth of the pig when added to purified rations However, inositol has been shown to stimulate biotin synthesis in the pig made deficient in biotin by including a sulfonamide in the ration This indicates that one of the functions of inositol is to stimulate biotin synthesis in the pig Undoubtedly, other vitamins may have an effect in stimulating synthesis of other factors in the intestinal tract, besides their role in metabolism or breakdown of food nutrients once they are absorbed from the digestive tract into the body system This field and its possible implications in swine nutrition is virtually unexplored

difficult to determine and cost the swine producer considerable money.

Work at Washington State (37) showed that pigs fed a purified ration lacking in all the B-complex vitamins did not show any specific vitamin deficiency symptoms. But the pigs failed to grow and looked like runts. This means that when all the vitamins were lacking, the nutritional level of the pig was so low that it failed to grow and thus failed to develop individual vitamin deficiency symptoms. So, a deficiency of a group of vitamins may exist on the farm without the pig exhibiting deficiency symptoms such as have been described by various experiment stations for single vitamin deficiencies. Especially is this so if the nutritional level is so low that growth is poor.

4.4 SINGLE VITAMIN DEFICIENCIES RARELY FOUND

Under farm conditions, one will usually not find a *single* vitamin deficiency. In almost every case, a *multiple* vitamin deficiency will exist. In other words, the deficiency symptoms may be a combination of symptoms described for the various single vitamins or it may be something entirely different. Conditions such as unthriftiness, reduced appetite, and poor growth are common to malnutrition in general. More studies are needed to determine the symptoms and performance obtained with pigs which have multiple deficiencies of the type which may be encountered on the farm under varying conditions of feeding and management.

4.5 NATURAL VS. PURIFIED RATIONS

Some data have been obtained with the pig showing that responses to vitamins may differ depending on whether they are being added to a purified or to a natural ration. Michigan workers (90,91,98) showed that the requirements of the pig for niacin, riboflavin, and pantothenic acid were considerably higher on a natural ration than the requirements established earlier from experiments using purified diets. They used a corn.

Michigan workers (96) showed that these three B-vitamins were of considerable value in preventing scours and enteritis in pigs Of considerable interest is the fact that the Michigan and Purdue workers (15,98) found that single additions of these vitamins failed to improve the performance of the pigs to any appreciable extent For best results the three B-vitamins, niacin, riboflavin, and pantothenic acid, needed to be added simultaneously This seems good evidence for adding all three B-vitamins rather than one alone to natural rations

These B-vitamins (niacin, riboflavin, and pantothenic acid) have been known and available for a good many years and yet they are not being so widely used as they should in supplementing swine rations Whereas some of the new factors being worked on are important, we should not lose sight of the vitamins which have been known for a good many years and which still are not being used so much as they should be Feeders and feed manufacturers should give serious consideration to making sure these three vitamins, plus B_{12}, are adequately supplied in swine rations Many investigators have shown B_{12} to benefit practical rations (3,8,16,26,39,41,49,86,94,95,106,117,118,126, 128) Thus, under practical feeding conditions, the B-complex vitamins most apt to be lacking are niacin, riboflavin, pantothenic acid, and B_{12}

4 8 VITAMINS NEEDED BY THE SOW

The sow has been shown to need the following vitamins in the ration A, D, thiamine, riboflavin, pantothenic acid, choline, pteroylglutamic acid, and B_{12} The other vitamins which have been shown to be needed by the pig for growth will undoubtedly be shown to be needed by the sow when studies on them are made Preliminary studies at Washington State showed that the addition of biotin, inositol, and para-aminobenzoic acid to purified rations was of no benefit (46)

Studies at Washington State showed that deleting from the ration any one of the three B-complex vitamins (thiamine, riboflavin, and choline) resulted in unsatisfactory reproduction (46)

4.7 SUPPLEMENTING RATIONS WITH VITAMINS

Studies at Michigan, Purdue, and Illinois (15,40,96,98,99) have shown that supplementing commonly used swine rations

Fig. 20. Note effect of B-vitamins supplementation on deficient pigs obtained from farms in Michigan. Top group of pigs were about 80 days old and averaged 20 pounds in weight. Note these same pigs after 35 days of vitamin supplementation. (Courtesy R. W. Luecke, Michigan Agricultural Experiment Station)

with niacin, riboflavin, and pantothenic acid was of considerable value in increasing the rate of gain and in decreasing the amount of feed required per 100 pounds gain. Moreover, the

not seem to be so pronounced as in reproduction, however (46)

The foregoing information on the effect of vitamin deficiencies on the sow certainly indicates the extreme importance of vitamins in the ration For example, a lack of riboflavin alone will cause all pigs to be born dead or cause them to die within 48 hours after birth A lack of pantothenic acid means that no pigs at all will be born In other words, a lack of either riboflavin or pantothenic acid means 100 per cent small pig losses Thus, everyone concerned should make sure that sow rations are properly fortified with vitamins Undoubtedly, a lack of vitamins in the ration accounts for many of the small pig losses which occur each year

4 9 UNIDENTIFIED FACTORS

High-quality alfalfa meal and pasture, animal protein concentrates, liver, soil, dried distillers' solubles, fish solubles, grass juice concentrate, dried whey, and other feeds have been shown to contain an unidentified factor or factors, useful either for the growing pig or for the sow during gestation and lactation Work at Washington State (33) and Florida (34) has shown that soil supplies an unidentified factor or factors for the young growing pig This does not mean that soil should be added to swine rations, but rather it emphasizes that young suckling pigs should have access to clean soil as soon as possible after birth Some very interesting and worth-while studies lie ahead in determining the unknown factors in these feeds their relationships, and their value in supplementing swine rations It is possible that some of these unknown factors may be identical with some of the newer factors which have been discovered recently

4 10 PASTURE WILL GO A LONG WAY

The use of lush, green pasture will minimize vitamin deficiencies in swine However, what many people consider a pasture is in many instances, no more than an exercise yard for pigs

In all cases, heavy pig mortality occurred. Feeding folic acid to gilts being fed purified rations appeared to improve their reproduction and lactation. The aid of folic acid in lactation did

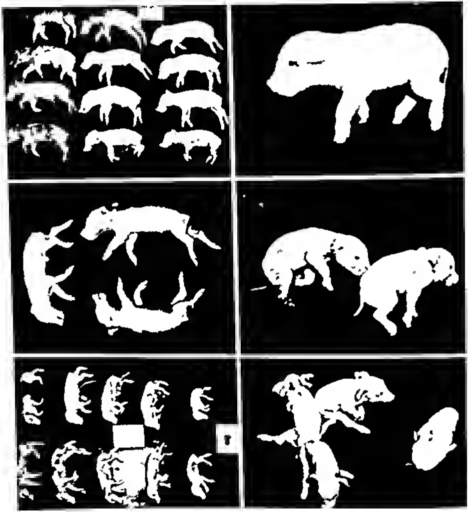

Fig. 21. A lack of B-vitamins causes poor reproduction. Three pictures on left are from riboflavin-deficient sows. Note enlarged front legs and generalized edema in some pigs. Litter in lower left was in process of resorption. All pigs were hairless. The pictures on right are of pigs representing leg weaknesses obtained with sows on rations where choline or thiamine was omitted. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

Fig. 22. Enlarged heart on right due to a thiamine deficiency. Heart on left is from pig fed same ration plus thiamine. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

Washington State experiments (59), it took at least 56 days for weanling pigs to lose their appetites after being fed a thiamine-deficient ration.

b. During reproduction and lactation gilts fed a thiamine-deficient ration at the Washington Station (48) had the following symptoms: (*1*) some loss of appetite, but not consistent; (*2*) parturition 9 and 11 days prematurely in two gilts; (*3*) high birth mortality in litters; (*4*) weak leg condition in pigs at birth; and (*5*) unthrifty pigs and subnormal weaning weights. The more depleted the gilts became in thiamine, the more severe the deficiency symptoms. From the 42nd to the 54th day after birth, three pigs in each litter were given 9 mg. of thiamine every second day. No apparent benefit on growth or external appearance was obtained from these injections. Tissue analyses showed that the gilts on the thiamine-deficient rations were very low in stored thiamine. Low thiamine storage also occurred in their young pigs.

4.11d Requirements

The National Research Council (7) recommends 0.5 mg. of thiamine per pound of total ration for swine during growth, re-

This needs to be considered by the feed manufacturer in compounding rations to be fed on pasture. Pasture needs to be kept short, lush, green, and leafy if it is to be of much value for pigs. In areas where the pasture season is of short duration, green, leafy alfalfa meal is an excellent pasture substitute. Considerable study is still needed to determine the vitamins needed in supplementing practical rations fed to swine on pasture. Work at Utah State (116) showed that alfalfa in the field supplies some factor or factors which is destroyed in the process of drying the alfalfa into hay. It will be interesting to know what this factor or factors turns out to be.

4.11 THIAMINE

4.11a Names Used Previously

Vitamin B_1, antiberiberi vitamin, antineuritic vitamin, oryzamin, torulin, polyneuramin, and aneurin are names previously applied to this vitamin.

4.11b Not Apt to Be Deficient in Swine Rations

Thiamine is widely distributed in feeds. For this reason a deficiency is not likely to occur in swine rations. Some good sources of thiamine are brewers' yeast, cereal grains, wheat bran, cull peas, rice bran, and plant protein concentrates. Pork itself is one of the richest sources of thiamine. See Table XX for the thiamine content of feeds.

4.11c Effects of Deficiency

a. During growth a lack of thiamine with weanling pigs causes diarrhea, vomiting, lack of appetite (anorexia), interruption of growth, slight staggering, enlarged and flabby hearts, a slight reduction in rectal temperature, heart beat, and respiration during the final stages of the deficiency, and finally death (47,59,66,133,134). Pigs can store thiamine and can use stored thiamine for a long period of time. Proof of this is that, in

Fig 23 Riboflavin deficiency The pig on top received no riboflavin in the diet, while the animal below received 3 mg of the vitamin per kilogram of solids (Courtesy R W Luecke, Michigan Agricultural Experiment Station and *Journal of Nutrition*)

production, and lactation (see Table I). This is slightly higher than the levels worked out by investigators and allows a small margin of safety (43,66,104,124). Increasing the level of fat in the ration lowers the thiamine needs of the pig as is the case with some other animal species. This means that fats have a "thiamine-sparing action" and that the fat content of the ration will affect requirements for this vitamin (43).

4.11e General Information

A positive relationship exists between thiamine intake and the deposition of this vitamin in the tissues of swine. This makes it possible to increase the amount of thiamine in pork by using feeds high in this vitamin. This has been shown by various investigators (59,100,105,114). Usually the loin and ham have the highest thiamine content, followed by the other cuts in the following order: shoulder, heart, liver, and kidney. A program of enriching pork by feeding rations high in this vitamin would increase the supply of thiamine in the American diet. This is important, because the average American diet is low in thiamine.

4.12 RIBOFLAVIN

4.12a Names Used Previously

Vitamin B_2, vitamin G, lactoflavin, ovoflavin, and uroflavin are previously used names for riboflavin.

4.12b May Be Deficient in Swine Rations

Many swine rations are borderline in supplying this vitamin, and many are deficient in riboflavin. Serious consideration should be given to adding a source of riboflavin to practical swine rations to make sure this vitamin is adequately supplied. Good natural sources of riboflavin are lush, green pasture, high-quality, leafy, green alfalfa meal, yeast, milk, milk by-products, dried distillers' solubles, dried brewers' yeast, plant protein concentrates, and high-quality meat scraps and fish meal. It must

enlarged front legs in some pigs, due to gelatinous edema in the connective tissue and generalized edema in many others, and (7) two hairless litters were born The longer the period of riboflavin depletion, the more severe the deficiency symptoms became Riboflavin-deficient gilts had low riboflavin storage and gave birth to pigs very low in riboflavin The above information was obtained at the Washington Station (48), but U S D A studies (102) also showed poor conception and reproduction with riboflavin-deficient rations

4 12d Requirements

The National Research Council (7) recommends 1 to 1 2 mg of riboflavin per pound of feed during growth and 1 2 mg per pound of feed for reproduction and lactation (see Table I) These National Research Council figures are not quite so high as those recommended by certain workers A U S D A study (102) shows that a level of 1 25 mg of riboflavin per pound of feed is the practical minimum level for breeding gilts and sows They also found that a level of 1 65 mg of riboflavin per pound of feed gave a slight improvement over the 1 25 mg level, but the results were not conclusive Thus, the riboflavin need of the sow may be above the 1 25 mg level An Illinois study (80) would also confirm this, since it was found that the gestation-lactation performance of sows was significantly improved by feeding rations containing 2 3 mg of riboflavin per pound as compared to 1 2 mg These figures are a little higher than the 1 2 mg level recommended by the National Research Council

The National Research Council recommendations on riboflavin levels for weanling pigs seems to be in agreement with those of most investigators A study at Illinois (81), however, showed that 1 4 mg of riboflavin per pound of ration was the minimum for weanling pigs fed in dry lot A later study by the U S D A (101) showed that 0 83 mg of riboflavin per pound of diet is adequate for growing swine Another Illinois study (107) was more in agreement with the U S D A results They found that, at 42 °F , the riboflavin requirement of the pig is 1 04 mg

be emphasized that grains are poor sources of riboflavin. See Table XX for the riboflavin content of feeds.

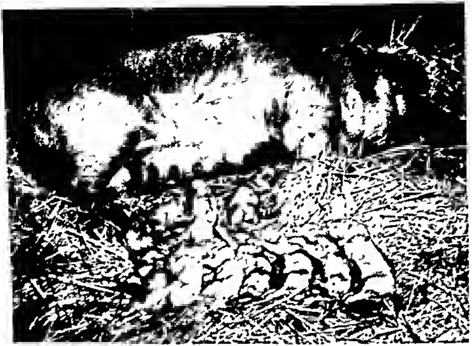

Fig. 24. Litter from a riboflavin-deficient sow. Seven pigs were born dead and the other three died within 48 hours. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

4.12c Effects of Deficiency

a. During growth a lack of riboflavin results in alopecia (loss of hair), anorexia (loss of appetite), poor growth, rough hair coat, dermatitis, scours, ulcerative colitis, inflammation of anal mucosa, vomiting, light sensitivity, eye lens opacities, unsteady gait, and many abnormal internal complications (65,84,103,135).

b. During reproduction and lactation gilts fed a riboflavin-deficient ration exhibited the following symptoms: (*1*) erratic or, at times, complete loss of appetite; (*2*) poor gains; (*3*) parturition 4 to 16 days prematurely; (*4*) one case of death of fetus in advanced stage with resorption in evidence; (*5*) all pigs either were dead at birth or died within 48 hours thereafter; (*6*)

4.13 NIACIN

4.13a Names Used Previously

Pellagra preventive factor, PP factor, pellagramine, vitamin PP, and niamid are names previously used for niacin.

4.13b May Be Deficient in Swine Rations

A deficiency of niacin is likely to occur when corn is a large part of the ration. Corn is a poor source of niacin. Barley and wheat have about twice as much niacin as corn. Many rations

Fig. 25 Colon of a niacin-deficient pig compared with a normal colon from a control pig receiving niacin Note darkened areas representing necrotic areas to which fecal material is firmly attached (Courtesy W. Burroughs, Iowa and Ohio Agricultural Experiment Stations and *Journal of Nutrition*)

are borderline in niacin content. Good sources of niacin are brewers' yeast, wheat bran, rice bran, rice polish, peanut meal, and dried distillers' solubles. See Table XX for the niacin content of feeds.

per pound of feed and at 85 °F. the requirement is lowered to 0.54 mg. per pound of feed. This showed that the riboflavin requirement of the pig is higher at a lower temperature. Recent work at the Illinois Station (122) showed that the riboflavin requirement of the growing pig is between 0.4 and 0.65 mg. per pound of the diet when the mean environmental temperature is 53 °F. They also found that, under the conditions of their experiment, B_{12} and aureomycin did not significantly influence the riboflavin requirements of the pig.

Recent studies at Michigan (103) indicate that the baby pig, shortly after birth, requires approximately 1.36 mg. of riboflavin per pound of diet. This is a higher riboflavin requirement than that of the weanling 30- to 40-pound pig.

This discussion indicates that more information is still needed on the riboflavin requirements of the pig at various stages in its life cycle and under varying conditions. Evidently, temperature affects riboflavin requirements. It has been shown that increased fat and lowered protein in the ration increases the riboflavin requirements of the rat. Possibly other factors may influence riboflavin requirements. More studies are needed with the pig to determine the exact requirements and why so much variation has occurred in the riboflavin requirements worked out to date.

4.12c General Information

Pork liver is higher in riboflavin than the other pork cuts and is followed in order by kidney, heart, ham, shoulder, and loin. Pork muscle contains much less riboflavin than thiamine. The pork heart, liver, and kidney, however, contain more riboflavin than the muscle tissue and more riboflavin than thiamine. The dietary level of riboflavin has much less effect on the tissue content of this vitamin than is true with thiamine. This means that one can enrich pork to a much higher level of thiamine than that of riboflavin by feeding rations higher in these two vitamins (47,59).

4 13d Requirements

The National Research Council (7) recommends a level of 5 to 8 mg of niacin per pound of feed for growing pigs and 5 mg of niacin per pound of feed for sows during reproduction and lactation (see Table I) This recommendation is in good agreement with niacin levels found by various investigators

More work is needed on determining niacin needs of swine, since the requirement for this vitamin is influenced by the protein and tryptophan content of the ration For example, Utah workers (136) were not able to produce a niacin deficiency in pigs on a ration containing 26 per cent casein But when the casein content was lowered to 10 per cent, niacin deficiency symptoms were produced This is because of an interrelationship between niacin and tryptophan (90,91)

Pigs can use the tryptophan to make niacin (see section 2 6b) Thus, if tryptophan is high enough in the ration (which occurs with a high casein diet), it is difficult to produce a niacin deficiency This means that the protein and tryptophan level in the ration is very important to know when niacin requirements are being worked out It also indicates that considerable variation would exist in niacin requirements depending on the ration used and the weight of the pig, since it has been shown that the niacin requirement of the pig decreases as the pig grows older and larger (13)

4 14 PANTOTHENIC ACID

4 14a Names Used Previously

The names antidermatitis factor, liver filtrate factor, and yeast filtrate factor have been used for pantothenic acid

4 14b May Be Deficient in Swine Rations

Many swine rations are borderline in supplying pantothenic acid and many are deficient in this vitamin Corn and soybean oil-meal rations are apt to be deficient in pantothenic acid

Fig 26. Niacin deficiency. Note retarded growth of pig on right which received the same ratio as pig on left except for niacin. (Courtesy M. M. Wintrobe, University of Utah, and *Journal of Nutrition*.)

4.13c Effects of Deficiency

a. During growth a deficiency of niacin in the weanling pig causes poor appetite, slow growth, rough haircoat, normocytic anemia, diarrhea, and a high incidence of necrotic lesions in the colon and cecum (17,19,64,90,91,115,136). Wide variation has been observed in the severity of symptoms in pigs with similar breeding and environmental backgrounds. Occasionally animals appear to thrive with no niacin, and other animals appear to vary in their requirement (115).

b. During reproduction and lactation it was not possible to produce a niacin deficiency with sows fed a purified diet when either 18 to 26.1 per cent casein was included in the ration in Washington State experiments (46). Evidently, the ration contained enough tryptophan to supply niacin needs or the sows were not fed the niacin-deficient ration long enough to develop a deficiency.

cytic anemia (28,67,68,85,129,132). It has been shown that the inclusion of biotin in the ration of a pantothenic-acid–deficient pig was effective in prolonging the life of the pig, but caused the pantothenic acid deficiency symptoms to appear in half the time. This may be due to some interrelationship of biotin and pantothenic acid (28)

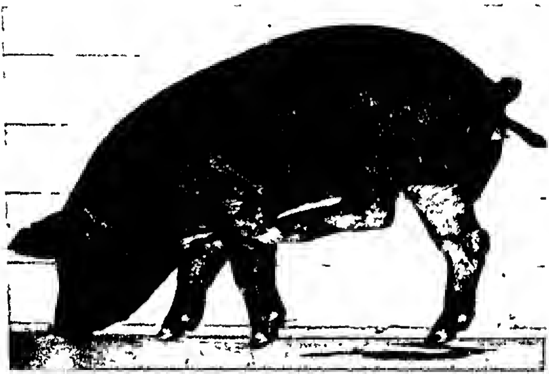

Fig 28 Note high stepping due to pantothenic acid deficiency in the pig (Courtesy R W. Luecke, Michigan Agricultural Experiment Station.)

b. During reproduction and lactation a study at the Washington Station (46) showed that a lack of pantothenic acid resulted in loss of appetite, reduced water intake, "goose-stepping" with hind legs, diarrhea, and rectal hemorrhages. Although the gilts became pregnant, they did not farrow or show any signs of pregnancy. An autopsy of the gilts revealed macerating feti in the uterine horns in all cases. Hemorrhagiconecrotic ceco-colitis, gastroenteritis, and catarrhal of the stomach and small intestine were also observed. Thus a lack of pantothenic acid resulted in complete reproduction failure. A recent study at

Good sources of pantothenic acid are: alfalfa meal, fish solubles, liver meal, cane molasses, peanut meal, dried whey, dried brewers' yeast, wheat bran, and distillers' solubles. See Table XX for the pantothenic acid content of feeds.

4.14c Effects of Deficiency

a. During growth a deficiency of pantothenic acid causes poor growth, excess lacrimation, coughing, decrease in appetite,

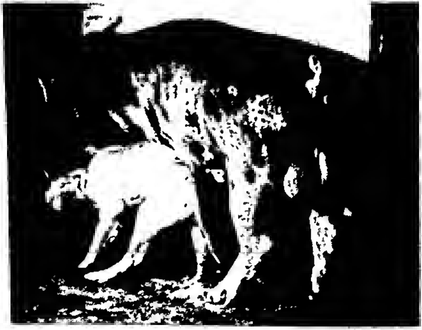

Fig. 27. Pantothenic acid deficiency. The smaller animal received the same diet as the larger one except pantothenic acid. (Courtesy M. M. Wintrobe, University of Utah.)

dermatitis, incoordinated movements of the hind legs, and a spastic gait (goose stepping), rough hair coat and skin, dark brown exudate around the eyes, excessive nasal secretion, diarrhea, loss of suckling reflexes and control of the tongue, loss of hair (alopecia), rectal hemorrhages, ulcerative colitis, low urinary excretion of pantothenic acid, and a moderate normo-

pound of diet, appeared to be adequate to support normal reproduction of sows

Another important aspect to consider in determining pantothenic acid needs is the finding by Michigan workers (89) that adding a mixture of synthetic B vitamins to a corn-soybean meal ration resulted in very severe symptoms of pantothenic-acid deficiency with weanling pigs However, if the same corn-soybean meal ration was fed alone, without any vitamins added, no symptoms of incoordination appeared

The reason for this may be that the pigs without any B vitamins grew so poorly that the level of pantothenic acid in the ration was sufficient to prevent symptoms of incoordination By adding the B vitamins to the ration, the researchers increased the growth rate This, in turn, increased the dietary requirements for pantothenic acid to the point where deficiency symptoms appeared

This means that the question of balance of B vitamins is very important from a practical standpoint If one is going to add B vitamins to a ration then all the vitamins which are apt to be lacking should be added If one, or more than one, is left out, a deficiency may be produced, while otherwise it would not occur unless the ration was partially fortified with other vitamins Work at the Iowa Station (27) has shown that pantothenic acid and vitamin B_{12} exert a "sparing" action on each other in the absence of aureomycin in the ration They also found that aureomycin appears to "spare" both pantothenic acid and vitamin B_{12} They also state that—with healthy, undepleted pigs weighing 35 to 45 pounds—a 14 per cent protein corn soybean oil meal ration balanced in other respects and containing adequate amounts of vitamin B_{12} and aureomycin need not be supplemented with pantothenic acid for optimum growth

On the other hand, Michigan workers (89,92,97) showed that pantothenic acid supplementation benefited pigs fed corn-soybean oil meal rations More work is needed on this problem and on determining the requirements for pantothenic acid of the pig under different conditions and with different rations

Illinois (123) showed that a dietary intake of 1.5 or 5.9 mg. of pantothenic acid per kilogram of diet was not sufficient to prevent development of deficiency symptoms. Gilts fed the 5.9 mg. level conceived, and gestation was supported to term. Abnormal pigs, however, were farrowed. No pigs were born to gilts receiving the 1.5 mg. level of pantothenic acid, although all but one individual exhibited estrus and were bred. Pantothenic-acid-deficient sows exhibited soft feces, diarrhea, bleeding from the anus, and locomotor incoordination which gradually progressed to "goose-stepping" and to eventual inability to rise. The pigs born to the sows fed 5.9 mg. of pantothenic acid per kilogram of diet showed a reduced desire to nurse. Severe muscular weakness, incoordination, and diarrhea increased until most of the pigs died.

4.14d Requirements

The National Research Council (7) recommends a level of 4.5 to 5.0 mg. of pantothenic acid per pound of total ration for the growing pig and 4.5 mg. per pound of feed for the sow during reproduction and lactation (see Table I). These recommended levels may be inadequate in some cases, according to data obtained at the Michigan Station (89,93). They found that for one-half of the pigs a level of 4.15 mg. of pantothenic acid per pound of feed was sufficient for normal growth, whereas for the remaining half of the pigs it was inadequate (93). Under their conditions, the requirement of the pig for pantothenic acid was greater than 4.15 mg. but less than 6.15 mg. per pound of feed. Evidently there is a wide variation in the requirements for pantothenic acid between individual animals. This should be taken into consideration in determining the vitamin needs of the pig. Vitamins supplied must be adequate for all pigs and not for just some of them. A recent Michigan study (121) showed that the pantothenic acid requirement of the baby pig for optimum growth and feed efficiency approximates 5.7 mg. of calcium pantothenate per pound of solids. A study at Illinois (123) showed that this same level of pantothenic acid, 5.7 mg. per

brown exudate around the eyes, low urinary excretion of pyridoxine, internal abnormalities, and impairment of vision (20,53,69,82,85,131).

b. During reproduction and lactation a deficiency of B_6 has not been studied experimentally with the sow. Undoubtedly, she needs B_6 for reproduction and lactation, but this has not been demonstrated experimentally.

4.15d Requirements

The National Research Council (7) recommends a level of 0.6 mg. of pyridoxine per pound of total feed for 25- and 50-pound pigs (see Table I). These are the only recommendations given. The level of pyridoxine recommended for 25- and 50-pound pigs should be adequate, since 2-day-old pigs did well on a ration containing 0.30 mg. per pound (82). Very little information is available on vitamin B_6 needs of the pig. No information is available on requirements for the growing pig or for the sow.

4.15e General Information

Vitamin B_6 includes three compounds which have B_6 activity. They are pyridoxine, pyridoxal, and pyridoxamine. Also, there may be other forms of pyridoxine. Pyridoxine, pyridoxal, and pyridoxamine are equal in activity for animals under many conditions. Under others, however, pyridoxal and pyridoxamine may show slightly less activity than pyridoxine. The three forms, however, show very different activities for many microorganisms. In plant tissues, all three forms of the vitamin occur in similar amounts. In yeast, glandular organs, and meats, however, most of the B_6 is present as pyridoxal and pyridoxamine with only traces of pyridoxine. Thus, vitamin B_6 studies need to consider the form of the vitamin in the feed as well as the effectiveness of each form in animal or microorganism response.

4.16 CHOLINE

4.16a Names Used Previously

Bilineurine was the name previously used for choline.

4.15 VITAMIN B_6 (PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE)

4.15a Names Used Previously

Vitamin H, factor Y, yeast eluate factor, adermin, antiacrodynia rat factor, and antidermatitis rat factor all have been used as names for vitamin B_6.

4.15b Not Apt to Be Deficient in Swine Rations

A deficiency of vitamin B_6 is not apt to occur in well-balanced rations. Few feeds can be classed as really poor sources. Good sources of B_6 are dried brewers' yeast, wheat bran, beef liver, cereal grains, fish, and meat.

4.15c Effects of Deficiency

a. During growth a deficiency of B_6 with the young pig causes poor appetite, microcytic hypochromic anemia, incoordination of the muscles, spastic gait, poor growth, fatty infiltration of the liver, epileptiform fits, coma, rough hair coats, a

Fig. 29. Vitamin B_6 deficiency. This pig is having an epileptic-like fit (Courtesy E. H Hughes and H Heitman, California Agricultural Experiment Staton.)

Illinois workers (110) These workers showed that the baby pig (2 days old when started on trial) needs 0 1 per cent choline (454 mg of choline per pound of feed) when fed a synthetic milk containing approximately 0 8 per cent methionine (30 per cent casein)

The level of methionine in the ration is important in determining choline needs Methionine can furnish methyl groups for choline synthesis Choline, however, is effective only in sparing methionine which otherwise would be used to make up for choline shortage Methionine is not used up for choline synthesis if there is an adequate level of choline in the ration Thus, the establishment of a choline requirement is complicated by the methionine level in the ration

Proof of this is the finding that, when 1 6 per cent methionine was included in the ration, it was not possible to produce a choline deficiency with baby pigs (109) The data with baby pigs on a synthetic ration, however, may not apply entirely with older pigs fed natural feeds So, other studies are needed to determine choline needs for growing pigs, as well as for sows during reproduction and lactation A level of 20 mg of choline per kilogram of body weight daily was used in Washington experiments with sows and prevented choline deficiency symptoms (48) This level, however, has not been determined as that needed by the sow

4 17 BIOTIN

4 17a Names Used Previously

The names vitamin H, coenzyme R, factor W, bios II, bios IIB, factor X, and anti-egg white injury factor have been used for biotin

4 17b Not Apt to Be Deficient in Swine Rations

Biotin is synthesized by the weanling pig (8 weeks old) in high enough amounts to supply its needs so far as is known (29,36,88) The 2 day old suckling pig evidently develops a biotin deficiency

4.16b Usually Not Deficient in Swine Rations

A choline deficiency is not apt to occur in practical, well-balanced swine rations. Good sources of choline are liver, wheat germ, cottonseed meal, soybean oil meal, peanut meal, tankage, and fish meal. Corn is low in choline—wheat, barley, and oats contain two to three times as much choline as corn. See Table XX for the choline content of feeds.

4.16c Effects of Deficiency

a. During growth a lack of choline in the ration of the young pig results in unthriftiness, poor conformation (short-legged and pot-bellied), lack of coordination in movements, a characteristic lack of proper rigidity in the joints (particularly the shoulders), fatty infiltration of the liver, characteristic renal glomerular occlusion, and some tubular epithelial necrosis (45,72,109,110, 130). These symptoms have been obtained with baby pigs on a ration containing 0.8 per cent methionine (110). Doubling the methionine content was effective in preventing these symptoms with the baby pig (109). This means that the methionine level in the ration is important when studying a choline deficiency.

b. During reproduction and lactation a lack of choline in the ration resulted in poor reproduction, lactation, and survival of young. Subnormal weaning weights and fatty livers were obtained with the young. No benefit, as far as appetite or increased gains, occurred from injecting half of the pigs of choline-deficient sows from the 42nd to 56th days of lactation. The pigs from choline-deficient sows were rough in appearance and became increasingly so with age (48).

4.16d Requirements

The National Research Council (7) recommends a level of 400 mg. of choline per pound of total ration for 25-pound pigs (see Table I). Recommendations for other weight pigs or for sows are not given. This level is about the same as that given by

a biotin deficiency (29,88). The avidin in the egg white ties up the biotin in the intestinal tract, making it unavailable to the pig; whereas the sulfathaladine decreased the intestinal synthesis of biotin. Sulfaguanidine feeding did not produce a biotin deficiency with the 8-week-old pig fed a purified ration (88).

Fig. 31. Note transverse cracking of the soles and top of the hoof of the biotin-deficient pig. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

b. During reproduction and lactation a biotin deficiency has not been produced experimentally with the sow. The addition of biotin to a purified ration was of no benefit to sows in a Washington experiment (46).

4.17d Requirements

The requirements of the pig for biotin have not been determined. With eight-week-old pigs, biotin deficiency symptoms were prevented, however, by feeding biotin at a level of 20

when fed a ration lacking in this vitamin. Evidently, the very young suckling pig does not synthesize enough biotin for its needs (83). Biotin is fairly well distributed in feeds. Thus, a lack of biotin is not likely to occur in swine rations. Good sources of biotin are liver, yeast, milk, and fish. Corn and wheat products are poor sources of biotin.

4.17c Effects of Deficiency

a. During growth a deficiency of biotin in the ration results in alopecia, spasticity of the hind legs; transverse cracking of the soles and top of the hoof; a dermatosis of the skin characterized

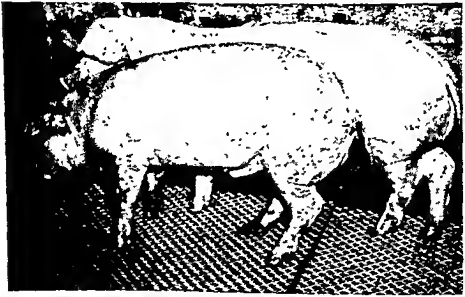

Fig. 30. Biotin deficiency. Both pigs received the same ration except that biotin was added to the ration of pig in back. Note loss of hair, dermatosis of skin, and cracking of feet of biotin-deficient pig. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

by dryness, roughness, a brownish exudate, and ulceration of the skin; and inflammation of the mouth mucosa (29,83,88). With the 8-week-old pig, the addition of 30 per cent desiccated egg white or sulfathalidine to a purified ration resulted in producing

and rats (31,119) These studies need more confirmation Other types of rations should be studied as well

4 18d Requirements

The requirements for inositol by the pig have not been determined Levels of 0 1 to 0 3 per cent inositol have been used in the ration (31,88,119) None of these levels, however, are regarded as definite requirements Many investigators have been able to obtain good growth with the pig and small laboratory animals without adding inositol to purified rations Other groups of workers, however, under different conditions, have shown that inositol benefits the pig and small laboratory animals Thus, under certain conditions, a need for inositol can be shown The reason for the need under those conditions is not known Since certain laboratory animals can synthesize inositol, it is logical to assume that under some conditions the intestinal synthesis of inositol is altered, thus altering the requirements of the animal Interrelationships of nutrients also occur, thus the ration fed and its content of various nutrients may influence the needs for inositol Substances, antimetabolites for example, in natural feeds may have an effect on the inositol needs of the animal There may also be some other explanation for this Regardless of the reason, considerably more work is needed to clear up the picture on the inositol needs and requirements of the pig

4 19 *p*-AMINOBENZOIC ACID (PABA)

4 19a Names Used Previously

Bx factor, vitamin Bx, chromotrichia factor, anti-gray hair factor, and trichochromogenic factor have been used as names for this vitamin

4.19b Not Apt to Be Deficient in Swine Rations

p-Aminobenzoic acid is not apt to be deficient in swine rations *p*-Aminobenzoic acid or PABA (as it is often abbreviated) is

micrograms per 100 grams of feed (88) or by injecting 100 micrograms of biotin per pig daily (29). These figures might be used as guides in the use of biotin until definite requirements are determined.

4.18 INOSITOL

4.18a Names Used Previously

The names *i*-inositol, *meso*-inositol, inosite, nucite, and dambose have been used for inositol.

4.18b Not Apt to Be Deficient in Swine Rations

Inositol is not apt to be deficient in swine rations. Inositol is widely distributed in feeds. Good sources of inositol are wheat germ, barley, oats, wheat, liver, and molasses.

4.18c Effects of Deficiency

a. During growth the addition of inositol to a purified ration was of no benefit with 8-week-old pigs. This would indicate either that the pig synthesizes enough inositol for its needs or that it does not need the vitamin added to the ration (36,88). In that trial, however, it was shown that if a biotin deficiency was produced by using sulfathalidine in the ration, inositol alleviated to a large extent the deficiency symptoms which were prevented entirely by biotin. A possible explanation is that inositol acted indirectly by stimulating the intestinal synthesis of biotin. Work with 1- and 4-day-old pigs at Illinois (72) showed no evidence for a PABA or inositol need when their combined deficiencies were superimposed on a choline deficiency; although their omission from the ration appeared to accentuate the degree of fatty infiltration of the liver.

b. During reproduction and lactation the addition of inositol to a purified ration for the sow was of no benefit (46). Wisconsin data, however, have shown that inositol was beneficial in lactation when added to a corn-soybean ration for brood sows

4.20b *Usually Not Deficient in Swine Rations*

As far as is known, a deficiency of pteroylglutamic acid (or PGA as it is abbreviated) is not likely to occur in practical swine rations. One study, however, has shown some benefit during early growth from adding PGA to a wheat-barley-tankage ration fed to 8-week-old pigs (36). This study needs to be repeated and other practical rations supplemented before it can definitely be stated that PGA is beneficial when added to practical swine rations. Good sources of PGA are liver, peanuts, and soybeans. The cereal grains are fair sources of PGA.

4.20c Effects of Deficiency

a. During growth baby pigs which received colostrum for 24 hours were successfully raised to 8 weeks of age on a synthetic milk ration (73). A clear-cut deficiency of PGA was not consistently produced on this synthetic milk diet even with the addition of a bacteriostatic agent (sulfathaladine). In one of the trials, however, the lower growth rate and lighter hair coats of the pigs indicated the beginning of a PGA deficiency.

Washington workers (30) found that PGA was needed for normal hematopoiesis if pigs (8 weeks old at the start) were fed a purified ration for a long period of time (21 weeks). A normocytic anemia was produced in pigs by adding sulfasuxidine to the ration for 21 weeks. Anemia was prevented by PGA and to a lesser extent by an anti-pernicious anemia liver extract. A more severe anemia was produced by using a crude PGA antagonist. A combination of PGA and biotin was more effective than PGA in counteracting the effect of the crude PGA antagonist.

Various other workers (21–24,54,60,75,127) have produced PGA deficiencies in the pig by a PGA antagonist or a sulfonamide. All studies showed that PGA is concerned with blood-cell formation. A more severe anemia (21) was produced with a 10 per cent casein diet than with a 26 per cent casein diet. This

widely distributed in feeds. Good sources of PABA are dried brewers' yeast, liver, alfalfa meal, wheat germ, and wheat middlings.

4.19c Effects of Deficiency

a. During growth, experiments at the Washington Station (36)—with 8-week-old pigs fed for 7 weeks—showed no beneficial effect on growth, efficiency of feed utilization, or external appearance when either PABA or folic acid was added alone or in combination with inositol and biotin to a purified ration. The addition of PABA or folic acid alone to the purified ration did, however, stimulate hemoglobin formation to a small extent. Illinois experiments (72) with 1- to 4-day-old pigs showed no definite evidence for a requirement for PABA or inositol when their combined deficiencies were superimposed on a choline deficiency, although their omission from the ration appeared to accentuate the degree of fatty infiltration of the liver.

b. During reproduction and lactation the addition of PABA to the ration of sows fed a purified ration was of no benefit (46).

4.19d Requirements

The requirement for PABA by the pig has not been determined. Levels of 10 mg. per 100 grams of feed (36) and 2.6 mg. per 1000 grams of milk (72) have been used for growing pigs and 20 mg. per 100 grams of feed for sows (46). None of these levels, however, are regarded as requirements. More studies are needed to determine the possible needs and requirements for PABA by the pig.

4.20 PTEROYLGLUTAMIC ACID (PGA)

4.20a *Names Used Previously*

Folic acid, vitamin Bc, vitamin M, L. casei factor, norite eluate factor, SLR factor, and factor U have all previously been used to designate this vitamin.

There is some relationship between leucovorin (synthetic citrovorum factor) and PGA. For certain microorganisms and for chicks and turkeys, leucovorin has some PGA activity. There is some evidence that before PGA can carry out some of its functions it must first be changed to leucovorin. It has also been shown that ascorbic acid is needed for this conversion.

In the future, some very interesting information will be obtained in unraveling the interrelationship of these vitamins and how they play their role in the nutrition of the animal. This incomplete information is being given since it may help the reader in understanding the complexity of certain interrelationships of these nutrients in the ration. It also helps explain why a certain balance between nutrients in the ration is needed for best results.

4.21 VITAMIN B_{12}

4.21a Names Used Previously

The names zoopherin, animal protein factor, erythrotin, factor X, and physin have been used for B_{12}.

4.21b May Be Deficient in Swine Rations

Many swine rations are borderline in supplying this vitamin and can be benefited by B_{12} supplementation. Good sources of vitamin B_{12} are liver, fish meal, fish solubles, peanut meal, meat scraps, and milk. The cereal grains are poor sources of B_{12}.

4.21c Effects of Deficiency

a During growth symptoms of a B_{12} deficiency show up in slower growth rate, rough hair coat, dermatitis, a tendency to roll over onto the side or back, hyperirritability, posterior incoordination, voice failure and pain in the rear quarters. Hematopoiesis is not normal as shown by high total erythroid counts in the bone marrow. A slight normocytic anemia also results (2,74,75,108,111,112,117).

would indicate, as has been also shown with rats, that PGA requirements are decreased at higher protein levels.

Since almost all the swine work on PGA has been conducted with high protein rations, this means that studies are needed with swine where lower levels of protein are used. One study with a natural ration, containing about 17 per cent protein, showed that PGA supplementation benefited growth during the first 4 weeks and caused the pigs to be cleaner in appearance and have bigger appetites at the end of the experimental period (36). This study indicates that work is needed with practical rations to determine whether PGA supplementation is needed.

b. During reproduction and lactation PGA supplementation was tried with a purified ration containing 26.1 per cent casein in Washington experiments (46). Indications were that PGA appeared to improve reproduction somewhat. Although it also seemed to aid in lactation, the effect was not so apparent as it was in reproduction. More studies are needed to determine the effect of a PGA deficiency in the sow and especially with lower protein rations.

4.20d Requirements

The requirements for PGA by the pig have not been determined. Levels of 50 to 100 micrograms of PGA per 100 grams of feed (30,36) for 8-week-old pigs, 0.05 mg. per liter of synthetic milk for 2-day-old pigs (73), and 200 micrograms per 100 grams of feed for sows (46) have been used successfully. None of these levels, however, are regarded as requirements.

4.20e General Information

The term *folacin* has been recommended for pteroylglutamic acid but has not yet received wide usage. The PGA molecule contains *p*-aminobenzoic acid (PABA). Some think PABA functions as a precursor of PGA; under some conditions this is true, but it is not known if this is always the case. This would be important to find out, since it would clear up the picture of PGA and PABA in animal nutrition.

micrograms of B_{12} per pound of total ration when added to a corn-soybean ration containing antibiotics (26,117,126). Studies at Illinois (108) showed that suckling pigs to 6 weeks of age require approximately 9 micrograms of B_{12} per pound of dry matter consumed. When B_{12} was injected instead of being fed orally, the requirement was approximately half this latter amount. More studies are needed to get more detailed information on the B_{12} needs of the pig during growth and for reproduction and lactation.

4.21c General Information

Other accepted names for vitamin B_{12} are: (*1*) cyanocobalamin (B_{12}) and (*2*) hydroxocobalamin (B_{12a} and $_{12b}$). Data obtained with a corn-peanut meal ration at the Florida Station showed that B_{12} alleviated the methionine needs of the pig (32,120). Pseudo-vitamin B_{12} has been shown to be inactive for the baby pig (51). It also appears that B_{12} is not involved in the synthesis of choline from methionine in the pig (50). Wisconsin data (79) showed that pigs which received a ration with vitamin B_{12} responded with an increased vitamin B_{12} activity of the muscle. The needs for B_{12} are increased as the level of protein is increased in the ration (25). Thus, the level of protein is important when B_{12} requirements are being studied.

4.22 VITAMIN B_{13}

A vitamin B_{13} concentrate has been shown to benefit growth in pigs fed a corn-peanut meal ration. Variation exists in the length of time required before B_{13} supplementation begins to increase the rate of gain, perhaps indicating that B_{13} is stored by the pig (35). An Illinois study (56) showed no beneficial effect in gestation or lactation when a B_{13} concentrate was added to a purified diet. Very little is known about this vitamin for the pig and more studies are needed.

b. During reproduction and lactation vitamin B_{12} has been shown to increase birth weights and livability of young pigs (125).

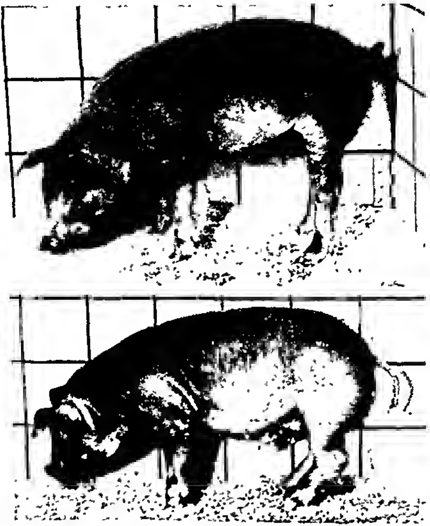

Fig. 32. Vitamin B_{12} deficiency. Both pigs were fed the same ration except pig in lower photo received B_{12} in the ration. (Courtesy D. V. Catron, Iowa Agricultural Experiment Station and *Journal of Nutrition*.)

4.21d Requirements

In a number of studies at the Iowa Station, it was found that the B_{12} requirement of the weanling pig is approximately 4 to 5

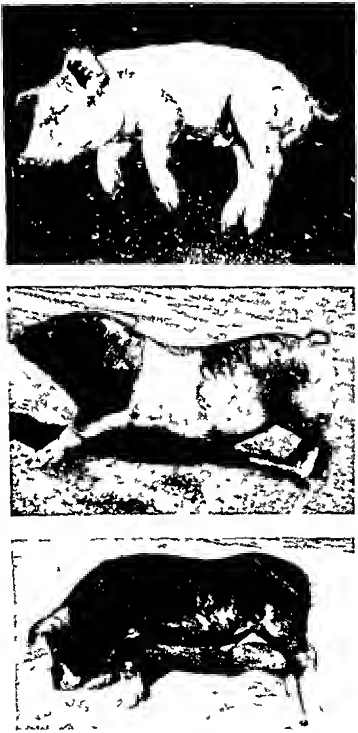

Fig 33 Vitamin A deficiency in growing pig Top photo shows a pig exhibiting partial paralysis and seborrhea, middle photo shows a pig in initial stage of spasm, botom photo shows a pig exhibiting lordosis and weakness of hind legs (Courtesy J F Hentges Jr, P H Phillips and G Bohstedt, Wisconsin Agricultural Experiment Station and *J Am Vet Med Assoc* (61))

4.23 ASCORBIC ACID (VITAMIN C)

4.23a Names Used Previously

Ascorbic acid has been called hexuronic acid, cevitamic acid, antiscorbutic vitamin, and scorbutamin.

4.23b Not Deficient in Swine Rations

The pig synthesizes all the vitamin C it needs; thus a deficiency is not apt to occur in swine feeding. Studies have shown no beneficial effect from adding vitamin C to swine rations for growth or reproduction (37,70,71).

4.24 VITAMIN A

4.24a Names Used Previously

Ophthalmin, anti-infective vitamin, biosterol, and fat-soluble A are names that have been applied to this vitamin.

4.24b Often Deficient in Swine Rations

Many swine rations are lacking in vitamin A activity. Thus, in compounding rations, one must make sure that the ration contains enough carotene to supply the needs of the pig. Good sources of vitamin A are fish liver oils, liver, eggs, and milk. Good sources of carotene are lush, green pasture, silage, and high-quality, leafy green alfalfa meal.

4.24c Effect of Deficiency

a. During growth a lack of vitamin A in the young pig caused a decrease of blood plasma vitamin A levels, a tendency to carry the head tilted to one side (an infection on the inner ear, otitis media, was found in each of these cases), incoordination of movement as exhibited by a swaying gait, paresis of the hind legs, gradual loss of control of the hind legs, weakness of the back, severe tonic spasms which lasted from 2 to 3 minutes, a seborrhea characterized by a brown, greasy exudate over the entire body

with the sow produced the following symptoms failure of estrus, resorption of young, wobbly gait, weaving and crossing of the hind legs at the walk, drooping of the ears, curving with head down to one side, spasms, loss of control of hind and fore quarters and thus inability to stand up, and impaired vision Depending on the degree of severity of the vitamin A deficiency, the fetuses were either resorbed, born dead, or carried to term Fetuses carried to term showed a variety of defects, including various stages of arrestment of formation of the eyes to a complete lack of eyeballs, harelips, cleft palate, misplaced kidneys, accessory earlike growths, some with one eye and some with one large and one small eye, and bilateral cryptorchidism (57,58,70) Vitamin A is stored for long periods of time, and it takes a considerable length of time to deplete pigs and sows of their reserve (14,57,58,61,62,70)

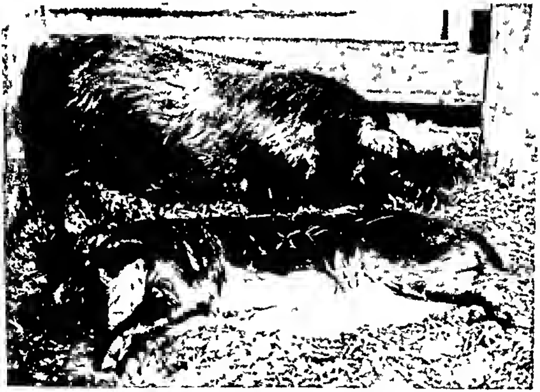

Fig 35 Vitamin A-deficient sow Note inability of the sow to stand (Courtesy J S Hughes, Kansas Agricultural Experiment Station)

surface, a rise in cerebrospinal fluid pressure, night blindness, constriction and degeneration of the optic nerves, and deaths from pneumonia. An effect of the vitamin A deficiency on

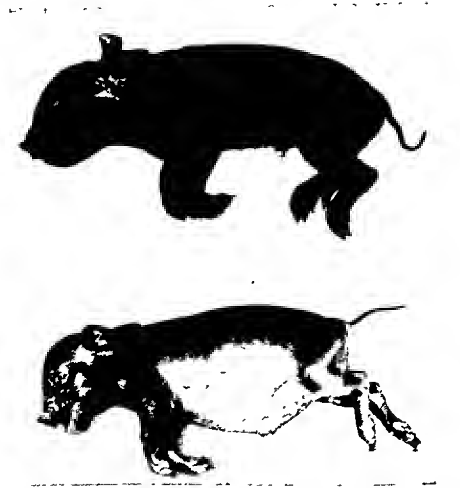

Fig. 34. Vitamin A deficiency in ration of the sow caused these pigs to be born blind. Note abnormality of the feet as well. (Courtesy Fred Hale, Texas Agricultural Experiment Station.)

appetite or rate of gain was not detected until eventual paralysis and weakness prohibited movement to the feeder (12,38,42,52, 57,61,70).

b. During reproduction and lactation a lack of vitamin A

for growth, gestation, and lactation for swine This means that the requirements of swine for carotene are higher than those for vitamin A English workers (111) showed that vitamin A alcohol and vitamin A natural ester are equally, or nearly equally, effective for pigs

4 25 VITAMIN D

4.25a Names Used Previously

Antirachitic vitamin, rachitasterol, and rachitamin are previously used terms for vitamin D

4.25b May Be Deficient in Swine Rations

Most of the commonly used feeds contain little or no vitamin D Fortunately, the action of sunlight on the skin of the pig produces vitamin D The skin contains the provitamin, and it is changed to the vitamin by the ultraviolet rays of the sun Summer sunlight is more potent than winter sun Thus, animals on pasture during the summer should never suffer from a vitamin D deficiency

In the winter, however, hogs are often outside only a part of the day and there are fewer sunny days So, it is unsafe to rely on winter sun to supply the vitamin D needs of the pig in the northern part of the United States This means that the vitamin D will need to be supplied in the ration or by a vitamin D supplement added to the ration More swine producers are now fattening out pigs inside away from pasture These men will need to make sure their rations are adequate in vitamin D

Good sources of vitamin D are sun-cured roughages, cod liver oil and other fish oils, and irradiated yeast Certain irradiated sterols are used as commercial sources of vitamin D for animal and poultry feeding

4 25c Effect of Deficiency

a. During growth a deficiency of vitamin D causes poor growth, stiffness and lameness, a general tendency to "go down"

4.24d Requirements

The National Research Council (7) recommends a level of 0.75 to 1.0 mg. of carotene per pound of total ration during growth and 2.5 mg. per pound of total ration for reproduction and lactation (see Table I). The recommended level for growth is a little higher than the requirements for the growing pig worked out by various investigators (12,38.57,62). The level recommended by the National Research Council should supply the needs of the growing pig as well as allow for a certain amount of storage. Very little information is available on the level of carotene needed for reproduction and lactation.

4.24e General Information

Names which are accepted for vitamin A are neovitamin A, axerophthol (vitamin A), and carotene. The carotenoids, which appear in nature and which are provitamins A (compounds which the animal changes into vitamin A), are alpha, beta, and gamma carotenes, cryptoxanthin, myxoxanthin, aphanin, aphanicin, echinenon, and torularhodin. Vitamin A exists only in the animal organism, whereas the provitamins A occur in both the vegetable and animal kingdoms. The pig converts the carotene into vitamin A in the intestinal wall.

Vitamin A, when given in great excess, causes toxic effects. It produces fractures of the long bones and death from hemorrhage in the rat. Very high levels of vitamins have not been studied with the pig. However, one should avoid large excesses of vitamin A in swine rations, because many laboratory animals—as well as human beings—have been shown to be adversely affected by excessive vitamin A. Most of the harmful effects have been obtained by feeding from 100 to 10,000 times daily requirements for long periods of time. Thus, small excesses of vitamin A for short periods of time should not exert any harmful effects.

California workers (110) and later Kansas workers (113) showed that unit for unit carotene is less effective than vitamin A

lesser amounts than colored pigs. These same workers in a later study (76) showed that an average of 45 minutes daily exposure to January sunshine for 2 weeks was sufficient to cure rickets. They found, however, that feeding pigs indoors and allowing them voluntary access to an outside pen was not a satisfactory way to cure rickets. The pigs did not go outside enough, presumably because of the cold or otherwise inclement weather during December and January. They also found that the need for vitamin D was inversely proportional to the calcium and phosphorus content of the ration.

Vitamin D is stored in the body for a long period of time, but not to the same extent as vitamin A. Thus, the pig resists a deficiency of vitamin D for a considerable time.

4.25c General Information

There are many sterol derivatives which have vitamin D activity. Vitamin D_2 and D_3, however, are the important ones in animal feeding. Vitamin D_2 is the form found in plant products such as hay and in irradiated yeast. Vitamin D_3 is the animal form found in fish oils, in irradiated milk, and in the body after irradiation. Both D_2 and D_3 have the same value for the pig, but D_3 is much more effective for chicks and turkeys. Vitamin D_2 (or calciferol) is obtained from ergosterol by irradiation. Vitamin D_3 (or activated 7-dehydrocholesterol) is obtained from 7-dehydrocholesterol by irradiation. Irradiated ergosterol (vitamin D_2) is sold for human use under the trade name Viosterol. Excess or massive doses of D_2 have been shown to be harmful and can even cause death. There is a wide range, however, between the recommended levels and the harmful dose. Nevertheless, since harmful effects can be obtained from overdosage, it is important to prevent excessive intakes.

4.26 VITAMIN E (TOCOPHEROL)

4.26a Names Used Previously

Vitamin E has also been called anti-sterility vitamin and factor X.

or lose the use of the limbs (posterior paralysis), frequent cases of fractures, softness of the bones, bone deformities, enlargement and erosion of joints, and unthriftiness (4,5,9,11,76,77,89).

Fig. 36. Vitamin D deficiency. Note abnormal legs and inability to stand properly. (Courtesy R. M. Bethke, Ohio Agricultural Experiment Station.)

b. During reproduction and lactation the sow undoubtedly needs vitamin D. The writer, however, was unable to locate any report showing the symptoms obtained with a vitamin D deficiency.

4.25d Requirements

The National Research Council (7) recommends a level of 90 I.U. of vitamin D per pound of total ration for growth, reproduction, and lactation (see Table I). The recommended level for growth is in agreement with an Ohio study (10). Vitamin D is needed for efficient utilization of calcium and phosphorus and, consequently, for normal calcification of growing bone. With an adequate intake of calcium and phosphorus and a proper ratio between them, less vitamin D is needed by the pig (4,9,76). No amount of vitamin D, however, will compensate for severe deficiencies of either calcium or phosphorus in the ration.

Minnesota workers (77) showed that white pigs resisted vitamin D deficiency symptoms about twice as long as colored pigs. The white pigs, however, still required vitamin D, even though in

More studies are needed on the vitamin E problem. Under certain conditions a need for vitamin E can be shown. It is not known, however, whether a vitamin E deficiency can be obtained under practical feeding conditions with well-balanced rations. It must be kept in mind that vitamin E is very susceptible to rancidity and the use of rancid feeds could cause a vitamin E deficiency. Thus, in studying vitamin E requirements this fact must be taken into consideration.

4.26d Requirements

No information is available on the vitamin E requirements of the pig for growth, reproduction, and lactation. Levels of alpha-tocopherol of 50 mg. daily for weanling pigs (88), 150 mg. daily for sows (46), and 1.00 mg. per kilogram of liquid milk (85) for baby pigs have been used successfully. None of these levels are to be taken as the requirements for the pig; however, they are a sample of some levels used by investigators with purified rations in swine work, and can be used as guides.

4.26e General Information

Vitamin E or tocopherol are accepted names for this vitamin. There are four forms of vitamin E. They are alpha, beta, gamma, and delta tocopherols. The alpha form is more active than the other forms in the cure of resorption and sterility in the rat.

There is no evidence that vitamin E in excess causes any harmful effects. This does not mean, however, that excessive levels should be used. Vitamin E is a strong antioxidant. Thus, it protects vitamin A, essential fatty acids, and other nutrients from destruction. It has been definitely shown that the vitamin A requirement of animals is partially dependent on the adequacy of the vitamin E content of the ration. Vitamin E is especially helpful when a borderline level of the vitamin A is fed.

4.26b Not Often Deficient in Swine Rations

Vitamin E is widely distributed in feeds, and a deficiency is not likely to occur in swine rations. Good sources of vitamin E are wheat germ oil, cereal grains (particularly in the germ and the hy-products containing the germ), alfalfa hay and meal, green forage, and liver, as well as soybean, peanut, and cottonseed oils.

4.26c Effect of Deficiency

a. During growth, the addition of wheat germ oil to the ration was of no benefit for the pig (6,137). The addition of vitamin E to purified rations was of no benefit for growth for the weanling pig (37). Alabama workers (63) were able to produce a fatal liver necrosis in growing pigs by feeding a diet deficient in vitamin E and containing 2 per cent cod-liver oil. The authors stated that without cod liver oil in the diet the liver necrosis would probably not have occurred since it is needed as a stress factor to develop the condition.

b. During reproduction and lactation a limited study with gilts (1), showed that a diet deficient in vitamin E caused lowered reproductive performance because of fetal death. Pigs from the sows reared on the deficient diet exhibited muscular incoordination caused by the disintegration of the muscle fibers. A study at the Hormel Institute (18) showed that supplementing the ration of the sow with vitamin E during gestation did not affect the size or apparent health of pigs at birth, but did favorably affect their livability and the growth of the nursing pigs under environmental conditions in which so-called baby pig disease was enzootic.

In another study, the addition of vitamin E to purified rations gave no benefit for reproducing and lactating sows (37). A study at Kansas (6) in 1932 showed a slight advantage for the feeding of 10 per cent wheat germ meal in the ration, but the difference was not large enough to be significant. There was some indication that the wheat germ meal improved the ability of the sows to milk. The wheat germ meal, however, could have been supplying needed factors other than vitamin E.

Very high levels of vitamin K cause harmful effects and even death Thus, very high levels should be avoided When vitamin K is deficient, the coagulation time of the blood is increased and the prothrombin level is decreased Thus, vitamin K is needed for prothrombin formation, which in turn is needed for blood coagulation Vitamin K is synthesized by microorganisms in the intestinal tract of the pig

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4.27 VITAMIN K

4.27a Names Used Previously

Coagulation vitamin, anti-hemorrhagic vitamin, prothrombin factor, and phylloquinones are names previously given to vitamin K.

4.27b Not Deficient in Swine Rations

The pig makes all the vitamin K it needs through intestinal synthesis. Thus, a deficiency of vitamin K is not likely to occur with swine. Good sources of vitamin K are green leafy hay or green leafy pasture, liver, and fish meal.

4.27c Effect of Deficiency

To the knowledge of the writer there is no experimental work showing a vitamin K deficiency in the pig.

4.27d Requirement

No information is available on the vitamin K requirements of the pig. Levels of menadione of 0.28 mg. per kilogram of liquid milk for baby pigs (85), 2.0 mg. per day for weanling pigs (88), and 10 mg. daily for sows (46) have been successfully used with purified rations. None of these levels, however, are to be taken as the requirements for the pig. Rather they are an example of levels which have been used in purified rations in many studies.

4.27e General Information

There are four important forms of vitamin K. Vitamin K_1 was isolated from alfalfa and K_2 from fish meal. Important forms of vitamin K made synthetically are phthiocol and especially menadione (2-methyl-1,4-naphthoquinone). Synthetic menadione is preferred in human clinics because it is highly effective and the least expensive to produce. Moreover, water-soluble forms of vitamin K are being made synthetically and are being used.

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CHAPTER V

Carbohydrate, Fat, and Water Needs of the Pig

5.0 CARBOHYDRATES

Carbohydrates make up about 75 per cent of the dry matter in most plants; thus they are the chief form of energy in swine rations. Sugars and starches are readily digested and have a high feeding value. The relative value of various grains and other high-carbohydrate feeds will be discussed later in Chapter VII.

5.0a Carbohydrate Use by Pig

Illinois workers (5) found that 1- to 2-day-old pigs react to sucrose feeding with severe diarrhea, rapid weight loss, unthriftiness, thinness, and death. Death usually followed 4 days of sucrose feeding. If the pigs were 7 days old when started on sucrose, however, about 60 per cent of them were able to utilize the sucrose. With pigs started on experiment at 9 weeks of age, sucrose produced equally as satisfactory results as glucose, dextrin, and corn starch.

It is not known why the newborn pig is not able to utilize sucrose. Possibly enzymatic activity is insufficient in the newborn pig to enable it to utilize sucrose (see section 6.3). But the ability of the pig to utilize sucrose increases with age—the reverse is true in the use of lactose by the pig. Newborn pigs can use lactose with excellent results, but their tolerance of lactose diminishes with age.

Illinois workers (4) showed that 9-week-old pigs could use 25 per cent lactose in the ration and perform satisfactorily. However, a 50 per cent level of lactose in the diet, a level the newborn pig can do well on, caused a pronounced depressing

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a beneficial effect are probably first changed to glucose before they are effective

Baby pigs like sugar, it is one of the most palatable ingredients that can be used in pig starters Pigs, like human beings, evidently have a sweet tooth and sugar is one of the ways of getting them to consume more starter feeds

Recent studies at the Iowa Station (19) have shown that baby pigs may not have fully developed enzyme systems for breaking down carbohydrates It will be interesting to follow the developments in this field and see what effect they will have on the utilization of various sources of carbohydrates by the baby pig This may explain the differences exhibited by the young pig in sucrose and lactose utilization (see section 6 3)

5.0b Fiber Utilization by the Pig

Pigs are less able to use crude fiber than other farm livestock Their digestive tract includes a simple stomach of relatively small capacity in contrast to the compound stomach of cattle and sheep and the large cecum of horses Cattle and sheep have a great deal of microbiological activity in the rumen This breaks down a large part of the crude fiber consumed (It is usually convenient to use the term crude fiber to designate the complex carbohydrates, such as cellulose and similar compounds, which are broken down by enzymes of microorganisms and not by enzymes secreted by the animal) Thus the pig is limited in the amount of crude fiber which it can use in the ration (25,26)

There is no agreement as to how much crude fiber pigs can use (3) This lack of agreement is probably due to differences in source of fiber fed, level of fiber in the ration, level of other nutrients in the ration, plane of nutrition, age and weight of the pigs, character of the nonfibrous part of the ration, as well as other factors It has been shown that the heavier the pig the more fiber it can use in the ration (22) The stage in which a forage is harvested also makes a great deal of difference in fiber digestibility for pigs Moreover, the amount of lignin in a

effect upon feed intake and growth rate. Besides, a moderate diarrhea was occasionally observed. Antibiotics tended to depress the severity of the adverse effects (except on efficiency of feed utilization) of the high level of lactose feeding. At 16 weeks of age, the pig was able to tolerate 25 per cent of lactose in the diet without harmful effect.

North Carolina workers (23) compared xylose to glucose in a purified diet for the 2-week-old pig. Xylose is one of the major constituents of wood molasses. The pigs fed xylose exhibited a depression of appetite, consumed less feed, grew

Fig. 37. Representative normal eye from a pig fed glucose (right); representative cataract eye from a pig fed xylose (left). (Courtesy E. R. Barrick, North Carolina Agricultural Experiment Station.)

at a slower rate, required more feed per pound of gain, had a lowered nitrogen retention, and developed cataracts. Moreover, voluntary activity was decreased and the hair coat color was altered from deep red to yellowish red in pigs fed xylose. These results would indicate that xylose has relatively little value as a source of energy for the growing pig.

Illinois workers (21) reported that the intravenous administration of sucrose, fructose, and lactose failed to resuscitate hypoglycemic comatose pigs and mannose, galactose, and maltose yielded slower responses than glucose in the comatose pig. Evidently, glucose is the most effective—probably the only—sugar that is immediately capable of resuscitating hypoglycemic coma in fasting newborn pigs. The other sugars which have

A reduction in the digestibility of the finishing ration by the introduction of crude fiber would seem to be a more practical method

Canadian workers (10) have shown, for example, that 25 per cent of the barley in the ration could be replaced with 25 per cent of either wheat bran or wild oats for 110-pound pigs In doing so, they produced a superior carcass without any change in rate of gain, feed intake, or length of feeding period Replacing the barley with 45 per cent alfalfa or 45 per cent bran, however, caused a decreased rate of gain and increased length of feeding period, but superior bacon carcasses were still produced These data and other information available in the United States would indicate that consideration needs to be given to the use of higher-fiber-content feeds during the latter part of the growing-fattening period as a means of producing a hog with more meat and less fat

Lard has been a drug on the market for quite a few years and considerable emphasis has been placed on producing a "meat type" hog Much can be accomplished in this direction by selection and breeding of a meat type animal and by feeding practices In certain areas, grain production is low and large quantities of alfalfa are grown There is much interest in substituting as much alfalfa as possible in the ration to increase the total feed available for swine feeding This practice would

TABLE XVI *Effect of Level of Alfalfa on Swine Performance (6 20)*

Level of alfalfa in the ration	Rate of gain and feed efficiency		
	Trial I	Trial II	Trial III
0			1 82 (306)
10	1 2[a] (451)[b]	1 7 (466)	1 72 (357)
30	1 1 (480)	1 6 (462)	
35			1 37 (404)
50		1 3 (574)	1 01 (543)
60	0 9 (530)		

[a] Rate of gain

[b] Feed per 100 lb gain

fibrous feed would affect the fiber digestibility (14). Thus, the study of fiber digestibility is not a simple task and a great deal of work still needs to be conducted on this subject.

5.0c Fiber Levels for Growing-Fattening Pigs

There is still considerable disagreement as to what level of fiber should be recommended for growing-fattening pigs (from 35 to 40 pounds up). Many would agree on a figure of 5 to 6 per cent fiber as the maximum to include in the ration, but some think a figure of 6 to 8 per cent may be used. The Wisconsin Station has conducted a great deal of work showing that levels of close to 8 per cent fiber can be satisfactorily fed to pigs providing the fibrous feed is finely ground and thoroughly mixed. Coarsely ground roughage in a swine mixture invites the pigs to sort out and waste feed in the trough or self-feeder. This means that fibrous feeds should be finely ground when used in swine feed mixtures. For example, Canadian workers (8) found that pigs gained faster when oats were ground finer. They also found that the fibrous portions, made up largely of hulls, were decidedly unpalatable to the younger pigs and, unless finely ground, were sorted out and refused.

Of considerable importance in determining the fiber level to use would be the quality of the fibrous feeds used. High-quality alfalfa meal and oats could be tolerated at higher levels than corncob meal, poor-quality roughages, and other fillers which might be used. This means that any increase in fiber levels allowed in swine rations would require control of the quality of fibrous feeds allowed.

Higher levels of fiber in swine rations can be used during the latter part of the fattening period. For example, it has been shown (9) that a restriction of the feed intake during the finishing period increases the quality of the hog carcass by reducing fat deposition during that period. Reduction of feed is only one way of causing this reduction in growth rate. On the farm, uniform restriction of feed intake for hand-fed groups of pigs is difficult, and it is impractical if self-feeding is carried out.

that 5 to 15 per cent high-quality alfalfa meal can be used in fattening pig rations

It might also be more desirable to feed a higher level of fiber to pigs which are going to be kept in the herd for breeding purposes Although these pigs will not gain as fast, the extra

Fig 38 High alfalfa rations produced an enlargement of the intestinal tract Viscera at left is from a conventionally fed hog Viscera at right is from an animal fed a 50 per cent alfalfa diet (Courtesy J F Kidwell, Max C Fleischmann College of Agriculture, University of Nevada)

fiber may provide a safeguard against overfatness and subsequent weak pasterns or breeding troubles It has been shown at the Wisconsin (11), Washington (12), and other stations that high-quality alfalfa meal contains a factor or factors which are definitely needed for reproduction and lactation It is stored for a long period of time Such storage is so important that the ration a pig receives during growth will definitely influence the ability of the animal to conceive, reproduce, and lactate many months later This means that prospective herd replacement gilts should be fed differently from pigs being fattened out for market—the herd replacements should get more alfalfa meal This will pay big dividends later by producing gilts that not only will settle quickly but that will also farrow large litters and wean a high percentage of their pigs

increase swine production in those areas. The Nevada Station (6,7,20) has recently conducted some work to show that high levels of alfalfa can be used for growing-fattening pigs. Some of their data are shown in Table XVI.

Their findings show that alfalfa can be fed to fattening hogs at higher levels than previously thought possible. The alfalfa-fed hogs were consistently leaner but had a lower dressing percentage. The hogs fed high levels of alfalfa produced more ham, loin, and shoulder and had less belly and fat back. Table XVII shows the data obtained at the Nevada Station on the carcasses of the pigs fed various levels of alfalfa.

TABLE XVII. The Effect of Alfalfa on the Carcass of the Pig (6)

Alfalfa, %	0	10	30	50
Back fat, in.	1.80	1.73	1.31	1.11
Carcass length, in.	29.6	29.8	30.0	30.3
Dressing percentage	74.6	73.0	69.6	68.1
		Per Cent of Carcass		
Loin	14.1	14.7	14.6	15.9
Ham	15.7	16.2	17.7	18.9
Shoulder	14.0	14.2	14.9	15.5
Bacon belly	13.7	14.1	13.3	12.4
Fat back	11.3	10.4	6.9	5.1
		Weight in Grams		
Stomach	508	504	587	618
Large intestine	1272	1522	1589	1684

The data show that as the pigs ate higher levels of alfalfa their digestive tracts enlarged to accommodate the increased fiber and bulk. The Nevada workers (20) found that pelleting the alfalfa-grain mix increased the rate of gain and the efficiency of feed utilization. They also feel that creep-feeding the pigs a ration with 25 per cent alfalfa conditions them so that they do better when fed high-level alfalfa rations after weaning.

In addition to the work at Nevada, other stations have shown

glands Fat deficiency symptoms began to appear after 42 days and were quite severe after 63 days Adding 1 5 per cent corn oil at that time caused an immediate increase in growth rate and some recovery of other deficiency symptoms

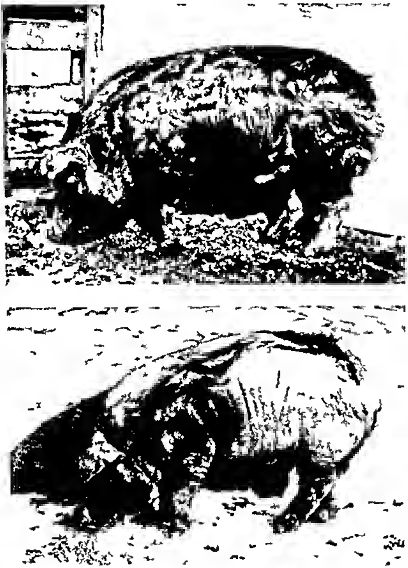

Fig 39 Fat deficiency Note loss of hair and scaly dandruff like dermatitis especially on the feet and tail of pig fed a fat deficient diet Pig on top received 5 per cent fat diet (Courtesy W M Beeson Purdue Agricultural Experiment Station)

Although the exact level of fat and/or fatty acids needed in swine rations has not been determined, data available would

The whole question of what fiber levels to use in swine rations needs some re-evaluation in view of the data on high-level alfalfa feeding and the emphasis being placed on the production of a meat type hog.

5.0d Fiber Levels for Sows

Rations for sows can contain more fiber than those for growing-fattening pigs. However, no definite level has heen established as the maximum. Many persons agree that sow rations may contain 10 to 12 per cent fiber. However, they qualify these figures by stating that these higher fiber levels should be allowed only to make use of higher levels of high-quality alfalfa meal and oats which are valuable constituents in sow rations. The use of high fiher levels will also tend to prevent sows from becoming too fat—a condition which can lead to poor results in reproduction.

Many swine producers are interested in making more use of pasture, silage, and other roughage feeds for sows. Experimental information already available indicates that more of these feeds can he included in sow rations with good results. There should be quite a few developments on using higher levels of fibrous feeds in sow rations in the near future. (See section 9.3f.)

5.1 FAT

5.1a Requirements

It has been shown at the Purdue Station (24) that the pig definitely needs fat in the ration. By using a semipurified ration which contained only 0.06 per cent fat, the following fat deficiency symptoms were obtained in the weanling pig: (*1*) loss of hair, (*2*) scaly dandruff-like dermatitis, (*3*) necrotic areas on the skin around the neck and shoulders, (*4*) unthrifty appearance, (*5*) retarded sexual maturity, (*6*) underdeveloped digestive system, (*7*) a very small gall bladder, (*8*) slower growth rate, (*9*) lower efficiency of feed utilization, and (*10*) enlarged thyroid

various levels up to 15 per cent of the ration of growing-fattening pigs The addition of 10 per cent of fat to the ration of fattening pigs has increased rate of gain 14 per cent and feed efficiency 18 per cent (13) However, the carcasses of the fat-fed hogs contained 0 13 to 0 21 inch more back-fat thickness and were considerably softer The Florida Station (18) fed levels of 10 and 15 per cent raw ground waste beef fat This added fat increased feed efficiency but there was no consistent effect on rate of gain There was, however, no adverse effect on carcass quality owing to the fat in the ration This information and that of other trials indicate that the addition of fat to the ration increases efficiency of feed utilization and sometimes rate of gain However, the carcasses may be fatter and softer This means that the kind of waste fat fed to swine is important and needs to be taken into account

It is well established that the iodine number (an indication of the degree of softness in fat) in the body fat of swine varies with the iodine number of the feed fat Thus, only fats which will not produce soft pork should be added to swine rations Most feed manufacturers, however, will probably consider using fat at low levels of only 1 or 2 per cent Whether adding fats at these low levels would affect carcass quality has not been determined Using fats at these low levels would minimize the problem and if the right kind of fat was used, there probably would be no problem whatsoever

This discussion certainly indicates that considerable information is still needed on adding fats to swine rations The final solution to the problem of surplus waste fat should not depend on feeding it back to animals Rather, this solution should lie in breeding and feeding swine that will produce more meat and less fat

5 2 WATER

Most people take the water they drink and the oxygen they breathe for granted and do not give it a second thought However, life would not exist for very long without these two im-

indicate that a level of 1.0 to 1.5 per cent fat in the ration is adequate. This indicates that practical swine rations consisting of grain and protein supplements should supply enough fat for the growing-fattening pig.

5.1b Inedible Animal Fats for Swine

The present problem in livestock production is not one of a fat deficiency but rather that of surplus fat. Since World War II, a gradual surplus of inedible animal fats has developed. In part, this has been due to the decreased use of animal fats by the soap industry, which has switched to the production of synthetic detergents, and to the housewife's preference for vegetable shortening for baking and cooking. In 1953, about two and one-half billion pounds of tallow and grease were produced, of which about one billion pounds were surplus. This surplus resulted in a significant decrease in the price of inedible animal fats, to the point which made them attractive as possible ingredients in animal feeds.

There are many advantages to adding animal fats to the ration. These are as follows: (*1*) controls dustiness of feeds, (*2*) improves feed efficiency, (*3*) increases acceptability and palatability, (*4*) improves physical appearance, (*5*) decreases wear on mixing and handling machinery, (*6*) increases comfort of workers in feed mill due to freedom from dust, (*7*) increases ease of pelleting, (*8*) reduces feed wastage in feeding, (*9*) reduces fire hazard from dusting, heating, etc., and (*10*) decreases carotene loss.

However, there are also some disadvantages to using animal fats in the ration: (*1*) They are difficult to handle, (*2*) they require special effort to maintain high quality, and (*3*) they need to be stabilized with a suitable antioxidant to prevent the development of rancidity (16,17).

Studies to date indicate that good-quality inedible fats should be a desirable ingredient in certain animal feeds, and an increasing tonnage is being used by the feed industry. Experimental studies (18) have shown that inedible fats can be used at

water higher than necessary to keep it from freezing No data are available, but it seems logical that cool or cooled water would be desirable for hogs during hot weather. This can be accomplished by maintaining the water supply in the shade to keep it from getting too warm

5.2b Effect of Source of Water

Ponds and stagnant waters of any kind are likely to be polluted Many disease outbreaks and parasite infestations are often traceable to contaminated water Thus, one needs to exercise caution in watering pigs from ponds Underground waters are usually free of pollution and are preferred as a source of farm supply Best results are obtained when the water is piped to well-located and protected troughs, rather than being carried by hand or hauled Pigs usually suffer from a lack of water when it is carried or hauled to them because the caretaker does not have or take the time to keep them supplied with water at all times

A preliminary trial conducted at the Florida Station (1) with growing-fattening pigs showed there was not much difference in the performance of the animals fed lake water, well water, distilled water, and water from an unpolluted pond Thus, if the water is clean and fresh there probably is not much to choose from in the source of water used for pigs

5 2c Effect of Salt and Alkaline Waters on the Pig

The question of salts in water is frequently raised by swine producers Work at the Oklahoma Station (15) has shown that animals accustomed to drinking fresh water will refuse salt water if they have access to salt regularly However, animals can gradually become accustomed to drinking water high in salts if no other water is available Tolerance to salt in the water depends on the kind of animal, its age, and the season of the year.

Feed consumption, as well as water intake, decreases as the salt content of the water increases The evidence available in-

portant essentials. A starving animal may lose nearly all of its fat, half of its body protein, and about 40 per cent of its body weight, and still live. But if it loses 10 per cent of its water, disorders will occur and if it loses 20 per cent of its body water, it will die.

Water is one of the most important nutrients required by swine and yet it is very often neglected. Water affords a medium for the digestion, absorption, and transportation of other nutrients throughout the body and for the elimination of waste products therefrom. Moreover, it plays a major role in the regulation of body temperature. A lack of water results in lowered appetite, lowered efficiency of feed utilization, and impairment of all body processes. Thus, it is apparent that an adequate supply of clean, fresh, palatable water should be readily available for animals to drink.

5.2a Requirements for Water

The daily water requirements of swine will vary from $^1/_2$ to $1^1/_2$ gallons per 100 pounds live weight. Young pigs and lactating sows have the highest requirements. Milk is over $^4/_5$ water and the small pig's body is about $^2/_3$ water. As the pig grows larger, it requires proportionately less water because it consumes less feed per unit of weight and the water content of its body is decreasing. Under normal conditions pigs consume a fairly constant amount of water for each pound of dry feed eaten. If some of the feed is high in water—such as silage, milk by-products, roots, or green forage—the amount of water consumed is correspondingly reduced.

Hogs require more water in hot weather than in cool weather. In very cold winter weather, a heating device should be used to keep the water from freezing. Recent Iowa Station (2) tests showed that pigs receiving water warmed to 45°F. gained an average of 0.14 pound per day more than pigs on unwarmed water which was frozen part of the time. Warming the water to 55°F. showed no advantage over warming to 45°F. Thus, there seems to be no advantage in keeping the temperature of

water higher than necessary to keep it from freezing No data are available, but it seems logical that cool or cooled water would be desirable for hogs during hot weather This can be accomplished by maintaining the water supply in the shade to keep it from getting too warm

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Feed consumption, as well as water intake, decreases as the salt content of the water increases The evidence available in-

dicates that much of the so-called salt injury is not a direct injury but rather a condition of partial starvation due to an intake of feed and water inadequate to satisfy the maintenance requirements of the animal. Hogs are more susceptible to salt injury than other domestic animals. They are able to tolerate water containing 1.0 per cent salt, but a level of 1.5 per cent salt in the water causes harmful effects and some deaths. Pigs fed 1.5 per cent salt water for 5 weeks soon became normal when returned to city water This further indicates that no injury was done save self-starvation.

Sodium chloride in water is somewhat less active than calcium chloride, and magnesium chloride is the most injurious. The injury evidently comes from the limited amount of water the animal will consume. Thus, alkaline waters are more injurious than salt waters.

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CHAPTER VI

Antibiotics, Surfactants, Arsenicals, Enzymes, and Hormones for Swine

6.0 ANTIBIOTICS

An antibiotic is a substance, produced by a microorganism, which has the capacity of inhibiting the growth of or destroying another microorganism. Hundreds of antibiotics exist, but only a few are beneficial for animal feeding.

The discovery and use of antibiotics in swine rations mark another milestone in the advancement in swine nutrition. Penicillin was discovered in 1942, and it was not until 1945 that it became available for public use. Thus, the antibiotic field is still relatively new and has developed rapidly. In 1949, it was first reported that products from aureomycin (chlortetracycline) fermentation promoted growth in pigs (29). At that time, it was found that what was then called animal protein factor (APF) supplements contained antibiotics and B_{12}.

The first published scientific paper showing the value of crystalline aureomycin in swine feeding appeared in April, 1950 (49). Since then "antibiotics" has become a common household word for swine producers as well as feed manufacturers and dealers. Prior to 1950, antibiotics were used for combating and treating pathogenic diseases in animals and human beings. In October of 1950, antibiotics were officially recognized and defined for animal feeding by the American Feed Control officials. Since 1950, a great deal of information has been obtained on antibiotics. More important is the fact that antibiotics are now a part of most feeds sold for growing-fattening pigs.

6.0a Antibiotics for Swine

This chapter contains some of the information which has been summarized in review papers (9,10,19,34,50,71). These review papers have summarized the many experiments which have been conducted with antibiotics in animal feeding throughout the world. Considerable use has been made of a review paper from the Florida Station, written in collaboration with Dr. R. Braude, of the University of Reading in England, which summarized the information available on antibiotics for swine (10).

6.0b Effect of Antibiotics in Swine Feeding

Following is a brief summary of the value of antibiotics in swine nutrition and feeding:

1. Aureomycin* and terramycin† are more effective than penicillin, bacitracin, and streptomycin for swine (10,14,27,33).

2. Antibiotics increase growth rate an average of 10 to 20 per cent. This results in the animal getting to market sooner, thus saving on labor and other costs. The better the overall nutritive value of the ration, in absence of disease level effect, the less the improvement in growth due to antibiotic additions. However, antibiotics are of benefit even with high-quality, well-balanced rations (10).

3. Antibiotics increase efficiency of feed utilization about 5 per cent. This means a saving of about 20 pounds of feed per 100 pounds of gain. Antibiotic response is confined to the growth rate and does not affect the final size of the animal. The saving in feed may appear small, but it adds up to a considerable saving to the swine industry.

Under conditions of stress, such as poor sanitation and low-quality rations, the improvement in efficiency of feed utilization is much greater. Since conditions of stress are common in average farm operations, antibiotic response may be greater there than under experiment station conditions. This must be

*American Cyanamid Co. trade-mark for the antibiotic chlortetracycline (CTC)

† Chas. Pfizer & Co., Inc., trade-mark for the antibiotic oxytetracycline (OTC)

kept in mind in applying the antibiotic data to average farm conditions (10,31).

4. Antibiotics increase bloom and appearance of animal (10).

5. Antibiotics help control certain types of nonspecific enteritis (scours). This is of considerable importance, since enteritis causes excessive loss to the farmer. Most investigators

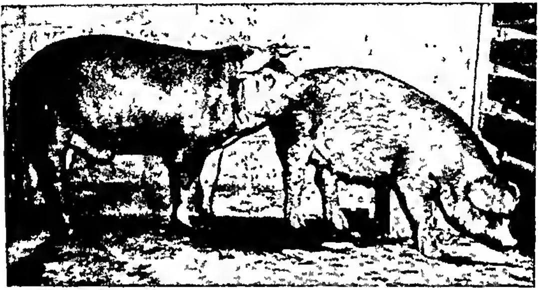

Fig 40. Note difference in bloom and smoothness of hair coat of antibiotic-fed pig as compared to control not fed an antibiotic (Courtesy T J. Cunha, Florida Agricultural Experiment Station)

are convinced that in swine nutrition the degree of effectiveness of antibiotic feeding is largely determined by the disease level. The disease level is defined as the degree of feed-lot infection with bacterial and/or virus disease which causes scouring or diarrhea in pigs. Thus, the theory (first proposed by Dr. Damon Catron of Iowa State) is that the higher the disease level, the more response the animal will give to antibiotic supplementation and the more antibiotic will be required (14,17,22,25,27, 63,66,68,69,81,82).

6. Antibiotics reduce the number of runts and thus allow pigs within litters to grow more uniformly in size. Runts or young pigs suffering from scours, respond to antibiotic feeding more markedly than normal pigs. In 12 comparisons, an average growth rate stimulation of 82.2 per cent was obtained.

Runts or "poor doers" in a herd of pigs are undesirable.

Considerable feed is lost or wasted with runt pigs. Moreover, they are more susceptible to disease infection and may spread trouble to the rest of the herd. Thus, the beneficial effect of antibiotics with runt pigs is of great economic importance to the swine producer (10,26,54).

7. It has been found that antibiotics tend to reduce the amount of protein supplement needed in the ration for swine. Protein is a costly item; a saving, no matter how small, would have major economic significance. It is not yet clear how much of the effect in reducing protein needs is due to the antibiotic and how much to a more adequate ration fortified with B_{12}, riboflavin, niacin, and pantothenic acid. Evidently, protein requirements have been high in the past because protein supplements were supplying factors other than amino acids. Previous to proper fortification of rations with antibiotics and vitamins, recommended rations for weanling pigs contained 20 to 22 per cent protein. Recent studies indicate that weanling pigs can now do as well on a ration containing only 14 per cent protein. This is a tremendous saving in protein and shows the value of proper supplementation with antibiotics and vitamins B_{12}, riboflavin, niacin, and pantothenic acid (10,12,23,30,32,37,46, 66).

8. The largest beneficial effect from antibiotics comes during the early growth period. Antibiotic supplementation benefits older animals, but they improve less than younger animals. When pigs get antibiotics to a weight of 75 to 125 pounds and then have them dropped from the diet, the pigs slow down in rate of gain and tend to gain like pigs not fed antibiotics. Pigs previously fed antibiotics maintain their early growth advantage for some time. However, for continued maximum growth, it is necessary to feed antibiotics from weaning to market weight (10,13,43,52,79).

9. Creep-feeding antibiotics to pigs during the suckling period will increase the weaning weight of pigs 5 to 10 pounds at 8 weeks of age. This extra weight enables these pigs to do better after weaning (10,42).

. . .

TABLE XVIII. Antibiotic Feeding Levels for Swine as Recommended by Eight Different Swine Specialists in U.S.

Fed to	1	2	3	4	5	6	7	8	Ave[d]	Range[e]
	Level of Antibiotic in Complete Mixed Ration (mg. per lb.)									
Sick pigs[f]	100	50	75[b]	75[c]	100[c]	37.5	50[a]	37.5	65.6	37.5–200
Unthrifty or runt pigs[f]	50	25	50[a]	35[a]	30[b]	37.5	25[a]	37.5	36.3	25–100
Pig pre-starters	100[a]	50	50[b]	20	80[b]	15	50[b]	10	46.9	10–100
Pig starters	50[a]	10	25[c]	15	30[b]	10	10[a]	6.25	19.5	6.25–50
Regular creep ration	50[a]	10	20[a]	10[a]	20[a]	7.5	10[a]	6.25	16.7	6.25–50
25 to 75 lb.	5[a]	5[a]	7.5[a]	7.5[a]	10[a]	5	5[a]	6.25	6.4	5–30
75 lb. to market weight	5[a]	4[b]	11[a]	4.5[a]	5[a]	5	5[a]	5	5.6	3–11
Sows—gestation and lactation	5	0[a]	20[b]	7.5[b]	5[a]	0	5[a]	—	6.1	0–20
Sows—3 to 5 days before and after farrowing	50	25[c]	20[b]	15[c]	100[b]	—	5[a]	—	35.8	5–150
	Level of Antibiotic in 35–40% Protein Supplement (mg. per lb.)									
25 to 75 lb.	80	50	50	—	80	40	70	40	58.6	35–100
75 lb. to market weight	80	50	50	—	40	—	70	50	56.7	40–100
Sows—gestation and lactation	70	0	—	—	40	—	60	—	42.5	40–100

[a] This was felt to be a fairly accurate figure by each swine specialist.

[b] This was thought to be about what the value should be, but there is not enough information definitely to indicate so.

[c] This was felt to be a rough guess based on little or no research.

[d] The eight swine specialists are considered to be some of the best research workers in this field. This average figure, as well as the individual recommendations, can be used as a guide in determining antibiotic levels to use.

[e] This is the range of recommended levels expressed by all the eight specialists. The wide range indicates much work remains to be done in determining more exact levels of antibiotics needed.

[f] It is suggested that pigs too sick to eat be given antibiotics in the drinking water. This will help the pigs get straightened out so that they will start eating again.

Note: These levels were recommended in the spring of 1956. Check with the experiment station and university personnel in your state or area for their recommendations, which might be somewhat different from these.

13 Several antibiotics, such as neomycin, subtilin, rimocidin, polymyxin, and chloromycetin,* have been tested and have not been of any benefit (10)

14 Nineteen comparisons conducted on pasture produced an average improvement in growth of 13 7 per cent and a corresponding saving of 3 8 per cent in feed as a result of antibiotic supplementation Thus, it appears that antibiotics are effective on pasture as well as in dry lot But they increase growth rate more under dry-lot feeding conditions (10)

15 Several studies have been specifically designed to determine the role of vitamin B_{12} as it relates to the antibiotic effect In these tests, the average growth response was 15 6 per cent for rations containing B_{12} and 11 0 per cent when B_{12} was not added From this evidence, it is apparent that the antibiotic stimulated growth regardless of B_{12} supplementation However, the best results were obtained when both were added Additional experiments are needed to clarify the relationship of antibiotic response to other B complex vitamins, however, indications are that antibiotics may spare certain B-complex vitamins, such as B_{12}, pantothenic acid, niacin, and riboflavin (10,11,25,38)

16 The antibiotic effect is materially influenced by the type of ration fed Other factors being equal, pigs fed a ration with better overall nutrient balance will respond less to antibiotic supplementation than those on a poorer ration Even on good *rations, antibiotic response varies depending on the feeds used* in the ration Thus, the quality of the ration as well as the kind of feeds used will affect antibiotic response (10,12,33)

17 Evidence on the value of antibiotics for sows during gestation and lactation is still inconclusive A few reports indicate that in some experiments the antibiotic is of value When fed at levels of 10 to 15 mg per pound of ration (20 to 30 grams per ton of feed), they may increase the birth weight, the number of pigs born, the number weaned, and weaning weights Some investigators, however, have found no beneficial effect Sows at the Florida Station have been fed aureomycin continuously and have produced five litters without any harmful effect

* Parke, Davis & Co trade mark for chloramphenicol

Data at the Georgia Station, with first- and second-generation animals, have shown no harmful effect and possibly a beneficial effect from including aureomycin in the ration for sows.

It is very possihle that the beneficial effect is apparent when stress factors such as quality of ration, disease level, and sanitary conditions are brought into play. With the data available, it is apparent that aureomycin feeding to sows is not harmful and may be of value in certain cases. Under average farm conditions, where sanitation is not always too good and where the ration is not always well balanced, it is possible that antibiotics may be beneficial for the sow (16,18,35,36,65,76,78).

18. Antibiotics are not transferred through the milk of sows in sufficient amounts to show a marked stimulation in the growth of nursing pigs. However, a small amount is transferred into the milk (10,55).

19. At the present time, the information available on the effect of antibiotics on swine carcasses is not in complete agreement. There are a few reports which indicate that antibiotics increase the depth of back fat and in general lower carcass quality. However, there are more reports which show that antihiotics do not interfere with carcass quality when fed in properly balanced rations. The Florida Station showed that aureomycin, per se, did not have any effect on carcass quality when feed intake was kept the same and the only difference between the rations was aureomycin. Studies presently under way should add considerably more to the knowledge in this field. It is possible that the breeding of the pig may account for some of the variation encountered on the effect of antibiotics on carcass composition (8,10,45,77,83).

20. A majority of experiments show that the subcutaneous implantation of baby pigs with antibiotic pellets is not effective in increasing weaning weights or livability (56,60,73,80).

21. Antibiotics have been shown to increase appetite. This causes the pig to eat more feed and thus gain faster and with increased efficiency (10).

22. Detectable amounts of aureomycin are not found in meat

even when the animals are fed at levels higher than usual. Moreover, cooking destroys many antibiotics. It has also been shown that the daily administration of small amounts of aureomycin for prolonged periods to children has not had any harmful effects and has been beneficial in some (48).

23. Antibiotics do not eliminate the necessity for practicing strict sanitation in swine production. However, they do make it possible to produce pigs under high-disease-level conditions where it was not possible before. Organisms which cause this high disease level are like weeds in a pasture. They do not kill the pasture but they lower the production rate because of competition for nutrients, etc. Thus, what we have considered as normal growth in the pig has been, in many cases, below normal because undesirable microorganisms in the digestive tract were holding back the animal to a certain extent. Thus, antibiotics may act as policemen to control the undesirable microorganisms.

This is a new concept, since most pigs, although apparently healthy in appearance, are actually suffering from various degrees of intestinal infection. Most hog producers use their same facilities year after year and in many cases keep crowding more animals into the same area. This means that their disease problem will increase and more attention will need to be paid to disease control and good sanitary practices. Antibiotics will be of great help in this problem, but they should be used with good sanitation and good management—not as a substitute for them.

24. As yet, there is no definite evidence which explains the manner in which antibiotics function. Work in England, at Beltsville, at the Texas Station, and elsewhere has shown that the growth-stimulating effect of antibiotics could not be duplicated by keeping chicks in isolation in new quarters where chicks had not been kept previously. All that work would imply, as has been thought by investigators, that antibiotics act upon some system connected directly or indirectly to the microbial flora of the host animal. However, exactly what takes place there is still not known.

Some of the possibilities are as follows: (1) increase of microorganisms which produce known or unknown vitamins or other growth-stimulating factor(s); (2) decrease of microorganisms which use up growth factors in the intestinal tract; (3) decrease of microorganisms which produce toxins or are pathogenic and thus cause slower growth (owing to subclinical infection or disease level effect); (4) decrease of microorganisms which interfere with absorption of food through intestinal wall; and (5) a combination of some or all of these possibilities or even others (10,11,24,39,61,62).

25. Data obtained at the Florida Station showed no difference in thiamine, riboflavin, or niacin deposition due to antibiotic feeding. This indicates that the antibiotic did not interfere with the deposition of these vitamins in the carcass of the pig (57).

26. There is very little, if any, danger from toxic effects of feeding practical levels of antibiotics to swine. The Iowa Station fed pigs from weaning to 100 pounds (55 days) on a ration containing 500 mg. of a combination of antibiotics per pound of total ration. Not only were no ill effects observed, but the pigs made very rapid gains of 1.41 pounds daily and required 217 pounds of feed per 100 pounds of gain. This provided an intake of as much as 2 grams of antibiotics per pig daily (19).

27. Since 1949, when antibiotics were first used, there has been a decreasing difference in the rate of growth between the pigs fed antibiotics and those used as controls. Some refer to this smaller difference as a decrease in the activity of antibiotics. A study of the records at experiment stations, however, shows that animals fed antibiotics today grow as rapidly as pigs fed similar rations in past years.

Actually what has happened is that control pigs not fed antibiotics are growing at a faster rate. They have improved progressively in rate of gain each year until now the difference in antibiotic-fed and the control animals is smaller. This is due to the cleaning up of the contamination of growth-inhibiting microorganisms by the antibiotics in the quarters where they have been used continuously.

Table XIX shows data on the rate of gain of pigs from the Minnesota Agricultural Experiment Station which illustrate this point (44)

TABLE XIX Effect of Antibiotic Feeding over Five-Year Period at Minnesota Station (40)

Year	Controls fed no antibiotic	Pigs fed aureomycin[a]	Pigs fed procaine penicillin[a]
1951	1 40	1 63	1 54
1952	1 45	1 63	1 55
1953	1 74	1 79	1 76
1953–54	1 59	1 73	1 67
1954–55	1 54	1 65	—

[a] *5 mg per pound of feed*

The pigs fed the aureomycin and penicillin are still gaining as rapidly as before It is the control pigs which are doing better and narrowing the difference This same finding has occurred at many other experiment stations

Of importance would be to know how long the cleanup of the premises lasts after the use of antibiotics for a number of years Very little evidence is available on this point Some investigators think, however, that recontamination may occur at any time, thus, it is a constant threat Swine producers should include antibiotics in the ration as a means of preventing recontamination and keeping the rate of gain of their animals at a high level

Canadian workers (7) have shown that the contamination of the quarters in which the pigs are fed increases their response to aureomycin For example, animals fed aureomycin in quarters where pigs had been kept before, gained at the rate of 1 29 pounds per day as compared to 0 96 pound daily for those fed the same ration without the aureomycin This was a 34 per cent increase in rate of gain due to aureomycin feeding There was only a 3 per cent increase in rate of gain, however, for pigs fed aureomycin (1 27 pounds daily) as compared to the controls (1 23

pounds daily) fed in a new barn where pigs previously had not been kept.

Thus, in the old barn where the control pigs were held back in rate of gain due to contamination, there was a big response to aureomycin feeding. In the new barn, where there was no contamination and the gain of the control pigs was not retarded, there was only a slight improvement from antibiotic feeding.

6.1 SURFACTANTS

Surfactants have been studied, but the results obtained have been variable and inconclusive. Antibiotics are generally more effective than the surface-active compounds thus far studied. At the moment, surfactants are an important topic for research, but they are not ready for commercial application in swine rations (6,10,59).

6.2 ARSENICALS

Several arsenicals such as 3-nitro-4-hydroxyphenyl arsonic acid, arsanilic acid, and other related compounds have been reported to have growth-promoting properties. Workers at the Hormel Institute and at the Universities of Minnesota and Nebraska have reported increased gains and an improvement in feed efficiency. Certain of these compounds also proved effective in the control of bloody dysentery. Of main concern regarding the use of arsenicals is that they are toxic substances with a fairly narrow range between toxic levels and those needed for optimum growth. Thus, the level of feeding must be carefully controlled. More studies are needed to establish the full value of arsenicals in swine feeding (10,15,40,41,44,64,81). Recent information indicates that arsenicals may have more of a place in swine feeding and enteritis control than heretofore.

6.3 ENZYMES

Recent studies at the Iowa Station (20,21,53) showed that baby pigs may not have fully developed enzyme systems for

breaking down proteins and carbohydrates. They found that soybean protein diets did not work satisfactorily for pigs from 1 to 5 weeks of age. However, the diets were satisfactory for pigs from 5 to 8 weeks of age. At this point, they surmised that the young pig up to 5 weeks of age might be deficient in proteolytic enzymes for digesting soybean protein. They found that early weaned pigs fed diets high in milk protein made quite satisfactory growth before and after 5 weeks of age. This showed that apparently the baby pig's digestive enzyme system is much more capable of breaking down milk protein than soybean protein during the first 5 weeks of life. Then they found that supplementation of the soybean diets with an enzyme (pancreatin or pepsin) improved growth rate (but not feed efficiency), approaching that obtained on a milk protein diet when lactose (milk sugar) was the principal carbohydrate. They confirmed the insufficiency of proteolytic enzymes in the baby pig by assays of the secretory glands of litter-mate pigs at birth and at consecutive weekly intervals until 7 weeks of age. The newborn pig has very little or no pepsin (enzyme) activity as shown by assays of the stomach mucosa. The pepsin activity, however, increases gradually up to 7 weeks of age. Assays of the pancreas indicated adequate trypsin activity from birth, but pancreatic amylase activity was very low in the newborn; however, it rose rapidly with age and reached a maximum at about 4 weeks of age.

Canadian workers (1,51) have confirmed the insufficiency of certain enzymes in the baby pig. They found (51) that the amylolytic (enzymes used in carbohydrate breakdown) activity of the pancreas, per unit weight of gland, is negligible in the newborn pig. The amylolytic activity increases rather markedly to 37 days of age. Their data suggested that amylase production undergoes a significant increase at 21 days or about the fourth week of life. They also found that the lipolytic (enzyme used in fat breakdown) activity of the digestive system of the young pig is of a high order at birth and remains high with advancing age.

The Canadian workers found (1) that lactase (enzyme that breaks down lactose) activity is high and sucrase and maltase (enzymes that break down sucrose and maltose, respectively) activity is low during the first few days of life. Lactase activity reaches a peak at roughly 3 weeks of age. Then there is a rapid decline to minimum levels at 4 to 5 weeks of age. Sucrase and maltase activity, however, rises steadily from negligible levels at birth to significant levels in 1 to 2 weeks. These findings would explain the reason why very young pigs are unable to utilize sucrose but can utilize lactose (see section 5.0a). The absence of sucrase in the intestine of young pigs could account for the failure of investigators successfully to formulate milk replacement formuli using sucrose for the very young baby pig. Moreover, the sharp decline in lactase activity in older pigs could explain the harmful effects of lactose for such animals (see section 5.0a).

These studies indicate that important changes occur in the digestive enzymes as early growth of the pig proceeds. These enzyme changes affect the suitability of various carbohydrates and proteins for the baby pig shortly after birth. The implications of these studies may be more far reaching than anticipated at the present.

6.4 HORMONES

The use of thyroprotein in swine rations has given variable results (84). In some trials, it has been beneficial, whereas in others it has not. This may be due to differences in environmental conditions, in the breed or strain used, in the dosage used, as well as the level of feeding plus the energy and nutrient content of the ration. Recent Iowa State studies indicate that thyroprotein feeding to sows a day or two before farrowing and up to 5 weeks after results in heavier pigs and $^1/_3$ to $^1/_2$ more pigs saved per litter (20).

The use of thiouracil in swine feeding may be useful during the last 4 weeks and possibly during the last 6 weeks of the fattening period (74). The feeding of thiouracil to weanling

pigs markedly retarded growth, reduced feed intake, and caused them to become sluggish, short, and chuffy (5,75) The feeding of thiouracil over long periods of time has also led to unfavorable results Thus, it seems that thiouracil should be used for short feeding periods and fed only to pigs shortly before marketing A recent U S D A study (47) has shown that the effect of thio uracil treatment of pigs may be modified or changed by differences in environmental temperature At a temperature near 50 °F thiouracil was beneficial, whereas it was not at 90 °F Thus, temperature is very important in evaluating the possible value of thiouracil It might be beneficial in winter and not during the summer

The use of diethylstilbestrol, either by implant or fed orally, has not consistently improved rate of gain or efficiency of feed utilization Usually there have been undesirable side effects, such as an increase in mammary tissue, in growth of the teats, and in size and congestion of the vulva (4) It has also been shown (72) that toxicity and death resulted in pigs fed a high level of stilbestrol of 20 mg per pound of feed This toxicity of stilbestrol needs further investigation

U S D A studies (70) were conducted to determine the effect on reproductive function of diethylstilbestrol administered orally to gilts It was found that ingestion of 2 5 to 25 mg of stilbestrol daily by gilts may temporarily interfere with reproductive function through inhibition of estrus, but permanent impairment did not occur at these levels Most of the gilts showed some uterine growth and mammary development

Recent work at Iowa State (28) showed that gilts followed steers fed 10 mg daily of stilbestrol in the ration without any harmful effects The gilts had access to the droppings of the steers and in addition were hand fed ground shelled corn, 4 0 pounds daily per head for 43 days and 2 0 pounds thereafter They were also fed whole oats, 2 0 pounds daily per head for 43 days and 4 0 pounds thereafter, plus 1 0 pound per head daily of a commercial pelleted supplement plus salt self fed The gilts were observed to work over the cattle droppings It must

be pointed out that these gilts were fed a considerable amount of supplementary feed and thus did not have to depend as much on the cattle droppings for extra nutrients. It is not known what might have happened if the gilts had been fed less feed and thus had consumed more manure. More studies are needed with larger numbers of gilts or sows and under different rates of supplementary feeding before this practice can be recommended without any reservation. To be on the safe side, therefore, it would be best to follow steers fed diethylstilbestrol only with pigs to be slaughtered and not with those to be kept for breeding purposes. If gilts are to be used, they should be bred first, since stilbestrol feeding will cause false heat periods and hence trouble in getting them bred. Recent unpublished work at Purdue (3) has shown that breeding boars should not be allowed to follow cattle fed stilbestrol in the feed, since it causes loss of sex drive and atrophy of the testes. Recent work by Beeson (3,58) at Purdue has shown that implantation with diethylstilbestrol is as effective as giving it in the feed. With implantation the cattle did well with 36 mg. of diethylstilbestrol implanted at the beginning of the trial; whereas when it is fed in the feed it requires 10 mg. of diethylstilbestrol per animal per day. Thus, cattle implanted with diethylstilbestrol will excrete only a small amount of it in the feces and hogs following them would not have anywhere near as much stilbestrol available in the manure. It will be interesting to determine if any harmful effects might occur with hogs following cattle which have been implanted with diethylstilbestrol. As yet, there is a lack of experimental information on this. However, it would certainly be much *safer to follow hogs after cattle getting* the *smaller level of* stilbestrol by implantation.

Most workers have reported that swine do not respond favorably to oral feeding or implantation of testosterone (4). A Florida study (67) showed that animals receiving testosterone alone, both barrows and gilts, rode each other frequently and ranted in a typical boarlike manner. Otherwise, the animals exhibited no outward manifestation of effects of the treatment.

They were somewhat trimmer and neater in the underline, with no tendency for production of seedy bellies The ovaries from the gilts were enlarged and cystic, while the entire genital tracts showed marked hyperemia and hyperplasia The seminal vesicles and prostate glands from the barrows receiving testosterone ranged from normal to slightly enlarged and hardened This information would indicate that it would be unwise to use testosterone for breeding animals on the basis of present knowledge

The information available to date indicates only little value in adding hormones in swine rations More studies are needed in this field to determine the variable results obtained with certain hormones The place of hormones in swine feeding is still not too clear and will require more studies

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CHAPTER VII

Relative Value of Feeds

7.0 INTRODUCTION

In compounding rations, one must select feeds which will make not only a well-balanced ration but also an economical one. Unless the ration is economical, the farmer cannot make a profit. This means one must be acquainted with the relative feeding value of feeds, as well as any limitations they may have in swine rations.

In selecting energy feeds or protein supplements, one must also consider the vit mins and minerals they contain or are lacking in. In selecting feeds, one should consider the purpose for which the feed is to be used; that is, for growth, fattening, gestation, lactation, and whether the feed is to be used in dry lot or on good pasture. Moreover, the ration must be palatable—the pigs must like it. All these factors must be considered in selecting feeds to be used in various swine rations.

7.1 DEFICIENCIES IN GRAINS OR ENERGY FEEDS

Grains and energy feeds contain some protein, vitamins, and minerals. However, they are too low in these for good results in swine feeding without supplements. These limitations are discussed in detail in Chapters II, III, and IV on proteins, minerals, and vitamins.

Proteins in the cereal grains are poor in quality and lacking in lysine. (See Table V for the amino acid content of various feeds.) Corn has a lower amount of lysine than the other cereal grains. Corn also has the lowest amount of tryptophan and is decidedly deficient in this amino acid.

Thus, protein supplements used to balance cereal grains must

TABLE XX. Feed Ingredient Analyses[a]

Ingredient	Protein, %	Fat, %	Fiber, %	N F E, %	Calcium, %	Phosphorus, %	Ash, %	Milligrams per pound: Thiamine	Riboflavin	Niacin	Pantothenic acid	Choline
Alfalfa meal (20% dehydrated)	20.0	2.5	20.0	38.0	1.7	0.20	11.0	3.0	7.5	23.0	18.0	400
Alfalfa meal (20% sun-cured)	20.0	2.5	20 0	40 0	1.4	0.20	10.0	2.0	7.0	23.0	12.5	400
Alfalfa (17% sun-cured)	17.0	2 0	25 0	38.0	1.4	0.20	10.0	1.1	5 0	16.0	12 0	*
Alfalfa meal (17% dehydrated)	17 0	2.5	25.0	39.0	1 6	0 20	9.0	1.5	6.5	20.0	12.5	400
Alfalfa meal (15% dehydrated)	15.0	2.0	28 0	36.0	1 4	0.20	9.0	1.2	6 0	18 0	11.0	400
Alfalfa meal (13% sun-cured)	14.0	1.5	30 0	36.0	1.2	0 20	8 5	1 5	5.0	18.0	10.0	400
Alfalfa stem meal	10.0	1 0	36.0	32.0	0.80	0 15	7.0	*	4 5	*	*	*
Babassu oil meal	22.0	6.0	12 0	44.0	0.10	0.70	5.0	*	0.6	*	*	*
Barley	12.0	2.0	6 0	67.0	0.09	0.30	2 8	1.7	0.6	24.0	3.5	500
Barley (Pacific coast)	9.0	2.0	6 5	68.0	0 05	0 40	2.2	1.8	0 6	20.0	3.0	425
Barley feed	11 0	2.5	12.0	57.0	0.03	0 40	4.5	*	*	*	*	*
Beans (Navy cull)	21.0	1 0	4 0	57 0	0.10	0 45	4 5	2.1	1.4	12.5	0.6	*
Beet pulp (dried)	9.0	1 0	19.0	58.0	0.60	0.05	3.5	0.1	0.5	9.0	0.8	*
Blood meal	80 0	1.0	1 0	1.0	0 30	0 25	3.3	0.2	1 5	18 0	2 3	540
Bone meal (cooked)	25.0	3.0	1 0	3 0	22 0	10 0	64.0	*	*	*	*	*
Bone meal (special steamed)	6 0	0.5	2.0	2.0	26 0	13.00	82.0	0.1	0 4	2 0	1.0	—
Bread (dried)	10.0	1.5	0.5	72 0	0 03	0.12	1.5	1.3	0.9	13.0	*	*
Brewers dried grains	24 0	6 0	15.0	42.0	0.20	0.50	3 8	0.3	0.5	18.7	6.0	600
Brewers dried yeast	45.0	1.2	2.5	35.0	0.10	1 5	7.0	45 0	14 0	215.0	50.0	2000
Buckwheat	10.0	2.0	10 0	62.0	0.05	0.30	2.0	1.8	0.9	11.0	5 6	*
Buckwheat middlings	28.0	6.5	7.0	40.0	0.15	1.00	4.5	*	*	*	*	*
Buckwheat feed	13.0	3.5	25.0	40.0	*	*	3.5	*	*	*	*	*

Buttermilk (condensed)	10.0	2.0	—	13.0	0.50	0.30	3.5	0.5	4.0	2.5	6.0	160
Buttermilk (dry)	32.0	5.0	0.3	42.0	1.30	1.00	10.0	1.7	12.0	7.0	13.0	800
Buttermilk (dry sweet cream)	33.0	5.0	0.2	43.0	1.30	1.00	9.0	*	14.0	7.5	14.0	800
Charcoal	—	—	80.0		*	*	3.5	—	—	—	—	—
Citrus pulp (dried)	6.0	4.0	15.0	60.0	2.00	0.10	7.0	0.6	1.0	9.6	6.0	*
Coconut oil meal	20.0	5.0	10.0	44.0	0.20	0.60	7.0	0.3	1.2	13.0	3.2	500
Corn (white)	9.0	4.0	2.5	68.0	0.02	0.25	1.3	2.0	0.5	8.4	1.6	—
Corn (yellow)	8.5	3.8	2.5	69.0	0.02	0.25	1.3	1.7	0.5	10.0	2.5	200
Corn and cob meal (yellow)	7.0	3.0	8.0	65.0	0.01	0.25	1.5	*	*	*	*	*
Corn bran	9.0	5.0	10.0	61.0	0.02	0.15	2.5	2.0	0.7	*	*	*
Corn cobs	2.0	0.5	33.0	54.0	0.01	*	1.5	*	*	*	*	*
Corn feed meal	9.0	4.0	3.0	70.0	0.03	0.30	2.0	*	*	*	*	*
Corn, flaked	8.0	3.0	3.5	71.5	0.02	0.25	1.3	*	*	*	*	*
Corn distillers' grains (light)	28.0	9.5	12.0	39.0	0.05	0.20	2.5	0.7	1.3	15.0	2.0	300
Corn distillers' grains (dark)	26.0	8.5	10.0	42.0	0.15	0.60	4.5	1.0	3.5	32.0	5.0	1000
Corn distillers' solubles (dried)	26.0	3.0	3.5	50.0	0.30	1.20	8.0	2.5	6.0	55.0	9.0	2000
Corn germ	14.5	4.5	8.5	57.0	*	*	*	*	*	*	*	*
Corn germ meal	20.0	6.0	9.0	53.0	0.05	0.55	3.0	0.4	2.0	16.0	1.8	800
Corn gluten feed	22.0	2.0	9.0	49.0	0.20	0.60	6.0	*	0.8	30.0	7.8	360
Corn gluten meal	42.0	1.5	4.0	41.0	0.20	0.40	2.5	0.1	0.7	24.8	3.8	125
Corn oil meal (solvent)	22.5	1.0	10.0	53.0	0.03	0.50	2.0	*	1.2	18.0	1.5	*
Corn oil meal (expeller)	22.0	5.0	10.0	49.0	0.05	0.55	2.5	4.3	2.0	17.0	2.0	*
Cottonseed meal (43%)	43.0	4.5	11.0	25.0	0.25	1.25	6.0	*	*	*	*	*
Cottonseed meal (41%)	41.0	5.0	12.5	27.0	0.20	1.10	6.0	1.8	2.5	13.0	4.4	1200
Cottonseed meal (41% solvent)	41.0	0.5	13.0	28.0	0.25	1.20	6.0	2.0	2.3	13.6	4.5	1200
Cottonseed meal (36%)	36.0	4.5	14.0	29.0	0.20	1.10	6.5	1.1	2.8	14.4	5.8	*
Cottonseed hulls	4.0	1.0	48.0	35.0	0.15	0.05	2.5	*	1.7	*	*	*
Crab meal	31.0	2.0	11.0	6.0	14.0	1.50	42.0	*	2.3	*	3.0	*

Continued

TABLE XX (*Continued*)

Ingredient	Protein, %	Fat, %	Fiber, %	N.F.E., %	Calcium, %	Phosphorus, %	Ash, %	Milligrams per pound: Thiamine	Riboflavin	Niacin	Pantothenic acid	Choline
Egg, dried whole	46.0	40.0	—	—	0.25	0.90	3.5	*	*	*	*	*
Egg, dried yolk	30.0	58.0	—	—	0.25	1.20	3.0	*	*	*	*	*
Emmer (spelt)	11.5	2.0	10.0	63.0	0.05	0.30	4.0	*	*	*	*	*
Feterita	11.0	3.0	2.5	70.0	0.02	0.30	2.0	*	*	*	*	*
Fish meal (menhaden)	60.0	6.0	1.0	4.0	5.00	3.25	18.0	0.2	2.4	25.0	4.2	1400
Fish meal (sardine)	65.0	5.0	1.0	5.0	4.00	2.50	15.0	0.2	2.5	26.0	1.3	1400
Fish meal (herring)	70.0	6.0	1.0	2.0	3.00	2.00	12.0	*	2.0	*	*	2000
Fish meal (white)	63.0	6.0	0.5	1.0	6.50	3.50	20.0	0.4	4.0	36.0	1.4	*
Fish meal (cod)	56.0	7.0	1.0	1.0	8.00	4.00	26.0	*	3.0	27.0	2.5	1400
Fish solubles (condensed)	33.0	3.0	—	3.0	0.10	0.80	9.0	3.2	6.0	130.0	18.0	1400
Flaxseed	22.0	32.0	7.0	24.0	0.25	0.65	4.0	*	*	*	*	*
Hempseed cake or meal	32.0	6.0	25.0	18.0	0.20	0.90	9.0	*	1.2	*	3.0	*
Hominy feed, white	10.5	5.5	5.0	66.0	0.05	0.80	2.5	5.0	1.0	25.0	3.0	*
Hominy feed, yellow	10.5	5.5	6.0	64.0	0.05	0.70	2.5	4.0	1.0	25.0	3.5	460
Kafir corn	11.0	3.0	2.5	71.0	0.03	0.30	2.0	1.6	0.5	18.0	5.7	200
Kafir head chops	10.0	2.5	7.0	66.0	0.08	0.20	3.5	*	*	*	*	*
Kelp, dried	6.0	0.5	8.0	44.0	1.00	0.25	35.0	*	2.0	25.0	1.0	150
Kudzu meal	13.0	2.0	30.0	41.0	2.75	0.20	7.0	*	3.4	*	*	*
Lespedeza meal	12.5	2.0	27.0	42.0	0.90	0.20	5.5	*	3.9	*	*	*
Linseed oil meal (old process)	34.0	4.0	8.5	36.5	0.40	0.90	5.8	1.2	1.8	18.0	6.0	900
Linseed oil meal (solvent)	36.0	1.0	8.5	37.0	0.40	0.90	5.9	3.0	1.9	20.0	6.5	950
Liver & glandular meal												

Malt (barley malt)	12 0	2 0	6 0	70 0	0 05	0 45	2 5	1 7	1 3	22 5	3 9	*
Malt sprouts	26 0	1 0	14 0	44 0	0 15	0 70	6 0	3 0	5 0	24 0	20 0	1000
Meat & bone scraps (50%)	50 0	8 0	2 5	2 0	10 00	4 80	28 0	0 5	2 0	22 0	1 8	900
Meat & bone scrap (solvent)	50 0	1 0	2 5	2 0	10 00	4 80	29 0	0 5	2 0	22 0	1 8	900
Meat & bone scraps (45%)	45 0	9 0	2 5	3 0	11 00	5 50	32 0	0 5	1 4	17 0	1 1	800
Meat scraps (55%)	55 0	8 0	2 5	2 0	8 00	3 80	20 0	0 5	2 5	30 0	2 2	1000
Meat meal (65%)	65 0	8 0	2 5	1 0	*	*	9 0	*	3 0	22 0	2 0	*
Millet seed (proso)	11 0	3 5	8 5	63 0	0 01	0 30	3 5	*	*	*	*	*
Millet seed (foxtail)	12 0	4 0	8 5	60 0	*	*	3 5	*	*	*	*	*
Milo maize	11 0	3 0	2 5	71 0	0 03	0 30	2 0	1 8	0 4	13 0	5 0	250
Milo head chops	10 0	2 5	7 0	67 0	0 15	0 25	3 5	*	0 9	*	*	*
Molasses, beet	9 0	—	—	62 0	0 05	0 02	10 0	*	—	20 0	*	*
Molasses, cane (blackstrap)	3 0	—	—	62 0	0 60	0 05	10 0	0 4	1 0	20 0	17 0	350
Molasses, corn (hydrol)	0 5	—	—	75 0	*	*	2 5	*	—	—	*	*
Oats	12 0	4 5	12 0	58 0	0 10	0 35	4 0	2 9	0 5	8 2	6 8	450
Oats (Pacific coast)	9 0	5 0	11 0	61 0	0 10	0 35	3 5	*No* exact data but probably similar to other oats				
Oat, clipped by-product	9 0	2 0	25 0	40 0	*	*	11 0	*	*	*	*	*
Oat groats (*hulled oats*)	16 0	5 5	2 0	65 0	0 10	0 45	2 0	2 0	0 45	8 2	5 0	560
Oat meal, feeding	15 0	6 0	3 0	64 0	0 05	0 40	2 5	3 5	0 6	4 5	6 5	*
Oat hulls	4 0	1 5	33 0	50 0	0 10	0 10	6 5	*	*	*	*	*
Oat mill by-product	4 5	1 5	30 0	52 0	0 20	0 20	6 0	*	*	*	*	*
Palm kernel cake	16 0	10 0	22 0	49 0	*	*	4 0	*	*	*	*	*
Peanut meal & hulls (O P)	45 0	4 5	14 0	23 0	0 10	0 50	5 5	3 3	2 3	77 5	24 0	800
Peanut meal (solvent)	50 0	1 0	7 0	27 0	0 10	0 50	6 0	*	*	*	*	*
Peanut hulls	5 0	1 0	70 0	12 0	*	*	5 5	*	*	*	*	*

Continued

TABLE XX (*Continued*)

Ingredient	Protein, %	Fat, %	Fiber, %	N.F.E., %	Calcium, %	Phosphorus, %	Ash, %	Milligrams per pound: Thiamine	Riboflavin	Niacin	Pantothenic acid	Choline
Rice (rough)	8.0	2.0	9.0	65.0	*	0.20	4.5	*	*	*	*	*
Rice bran	12.0	12.0	13.0	42.0	0.10	1.30	10.0	10.3	1.4	129.0	10.0	*
Rice polishings	12.5	11.0	3.5	56.0	0.05	1.10	6.0	8.8	0.9	325.0	5.5	550
Rice hulls	3.0	0.5	36.0	34.0	*	*	17.0	—	—	—	—	—
Rye	12.0	1.5	2.5	70.0	0.01	0.30	2.0	2.0	0.7	7.0	4.0	*
Rye distillers' grains, dried	18.0	6.0	18.0	48.0	0.10	0.45	3.5	0.8	1.5	7.6	3.0	*
Rye feed	16.0	3.5	6.0	62.0	*	0.45	4.0	*	*	7.5	10.0	*
Sesame oil meal	40.0	9.0	6.5	23.0	2.00	1.60	12.0	2.0	0.7	7.0	4.0	*
Shrimp meal	40.0	2.0	9.5	1.0	*	*	33.0	*	1.0	*	*	*
Skim milk, dry	34.0	1.0	0.1	50.0	1.30	1.00	8.0	1.6	9.3	6.0	16.0	500
Soybeans	36.0	17.0	5.0	24.0	0.20	0.60	5.0	5.0	1.2	10.0	7.1	1300
Soybean oil meal (expeller)	42.0	5.0	6.0	30.0	0.25	0.60	7.0	1.0	1.4	16.0	6.3	1200
Soybean oil meal (solvent)	45.0	0.5	6.0	31.0	0.25	0.60	6.0	1.4	1.4	16.0	6.2	1300
Soybean mill feed	18.0	1.0	23.0	38.0	*	*	4.5	*	*	*	*	*
Sunflower seed	16.0	20.0	30.0	21.0	0.20	0.50	3.0	0.2	*	*	*	*
Tankage (dry rendered)	58.0	8.0	1.5	2.0	6.00	3.25	23.0	*	1.9	22.0	1.7	*
Tankage (60%)	60.0	6.0	2.0	1.5	6.50	3.50	20.0	0.1	1.0	18.0	1.0	900
Tankage (50%)	50.0	6.0	2.5	2.5	10.00	5.00	26.0	—	0.7	13.0	0.7	800
Tomato pomace (dried)	22.0	14.0	20.0	23.0	*	*	3.0	5.5	2.7	*	*	*
Vinegar grains	18.0	6.0	19.0	46.0	*	*	2.5	*	*	*	*	*

Wheat, hard winter or spring	15 0	2 0	3 0	68 0	0 05	0 40	1 8	2 3	0 5	28 0	6 0	450
Wheat (soft western)	10 0	2 0	3 0	72 0	0 05	0 30	2 0	2 2	0 5	26 0	5 2	360
Wheat, flaked	12 0	1 5	3 5	67 0	0 05	0 35	2 0	*	*	*	*	*
Wheat bran	15 0	4 0	10 0	53 0	0 10	1 20	6 0	3 6	1 0	60 0	13 0	600
Wheat brown shorts	16 0	4 5	7 5	56 0	0 10	0 90	5 0	7 0	1 1	40 0	9 0	530
Wheat flour middlings	16 0	4 5	6 0	59 0	0 05	0 60	3 5	6 0	0 8	44 0	4 5	450
Wheat germ meal	25 0	7 0	3 0	44 0	0 05	1 00	5 0	11 0	2 2	23 0	5 0	1300
Wheat grey shorts	16 5	4 5	6 0	55 0	0 05	0 75	4 0	Vitamin content like flour middlings				
Wheat low grade flour	12 0	2 0	1 5	70 0	0 05	0 30	1 2	*	0 4	*	*	*
Wheat mixed feed	16 0	4 5	8 0	56 0	0 10	0 90	4 5	Vitamin content similar to middlings				
Wheat red dog flour	16 0	3 5	3 0	62 0	0 05	0 50	3 0	9 0	0 5	25 0	6 2	450
Wheat standard middlings	16 0	4 5	7 0	56 0	0 10	0 80	4 2	5 8	0 8	44 0	9 0	540
Whey, dry whole	12 0	1 0	0 2	70 0	0 90	0 70	9 5	1 8	10 0	5 0	20 0	800
Yeast dried grains	20 0	2 0	16 0	47 0	*	*	3 0	*	*	*	*	*

[a] This table is prepared for use in calculating the nutrients in a feed All mixed or formula feeds require minimum guarantees of protein and fat, and the maximum fiber content Average analyses for these nutrients are not shown, but instead round numbers have been used, which for protein, fat and N F E are slightly lower (a fraction of a per cent) than the average, for fiber the figure is slightly higher Using these figures results in easier calculations, and also in a safe guaranteed analysis Calcium, phosphorus and ash figures are indicated in much the same manner Vitamin figures are based on up-to date assays In most instances published figures are used, but in some cases unpublished values have been used These values are believed to be factual but one must remember that vitamin values vary appreciably in some materials, whereas in others they are quite uniform An asterisk (*) is used where values are unknown Blank spaces indicate no value These data were compiled by C W Sievert and B W Fairbanks The author gratefully acknowledges their permission and that of *The Feed Bag Red Book 1956* for reproducing these data

supply not only enough protein but also protein having a good balance of the essential amino acids. Since corn contains the lowest amount of protein of the cereal grains and grain sorghums, more protein supplement is needed to balance a corn ration than one containing wheat, barley, oats, or grain sorghums. This must be considered in deciding which grains to use at given prices.

All energy feeds are lacking in calcium, salt, and vitamin D. Grains are fair sources of phosphorus, but only yellow corn and its by-products contain appreciable amounts of carotene (provitamin A). The grains are all good sources of thiamine but are inadequate in riboflavin content. Barley, wheat, and the grain sorghums are fairly good sources of niacin, whereas corn, oats, and rye are lower and sometimes borderline in this vitamin. (See Table XX.)

If the ration contains a good supply of tryptophan, the pig can make niacin from it in its body and thus reduce the amount of niacin needed in the ration (see section 2.6b). Since corn is deficient in tryptophan and the other grains are borderline in its content, it is necessary that rations contain adequate amounts of niacin for the pig. Oats, wheat, rye, and the grain sorghums contain almost twice as much pantothenic acid as corn and barley (see Table XX). Many corn and barley rations are borderline or deficient in pantothenic acid. All grains are lacking in vitamin B_{12}. Since grains form a large part of the ration, many swine rations are borderline or deficient and need supplementation with riboflavin, niacin, pantothenic acid, and vitamin B_{12}.

7.2 RELATIVE VALUE OF GRAIN FEEDS

The cereal grains and their by-products furnish the bulk of the fattening feeds for hogs. Following is a discussion of their value in swine rations. Table XXI gives the relative feeding value of the grain feeds for swine.

TABLE XXI Relative Feeding Value of Grain Feeds for Swine

Feed	Pounds per bushel	Bushels per ton	Relative value as compared to corn with corn given a value of 100	
			Range	Avg figure
Corn, shelled	56	35 7		100
Wheat	60	33 3	103–106	105
Barley	48	41 7	87– 92	90
Oats	32	62 5	75–100	90[a]
Grain sorghums	55	36 3	85– 95	90
Rye	56	35 7	84– 92	90

[a] This value will vary depending on the amount fed in the ration At levels of 20–30% of the ration for young pigs and brood sows they are almost as valuable as corn

7 2a Corn

Corn is the grain feed around which the major portion of swine rations are balanced (see Table XXIII) The feeding value of corn is used as the standard with which other cereal grains are compared White and yellow corn have the same feeding value, provided the ration contains enough carotene or vitamin A, either from pasture or from some other source if fed in dry lot It seldom pays to grind or soak corn when it is fed free-choice If the kernels are too hard and dry, however, it should be coarsely ground Corn should also be ground if it is to be mixed with other grains and a supplement The dry matter in soft corn has the same feeding value as the dry matter in sound corn, but the gains on soft corn are usually not so rapid When beginning to feed soft corn (corn frosted before maturity) or new corn, the change should be made gradually to minimize digestive trouble

7 2b Oats

Oats are an excellent feed for young, growing pigs and sows (see Tables XXIII, XXXI, and XXXII) They are too high in fiber and too bulky, however, to form a major portion of the

ration for young, growing pigs. When limited to 20 to 30 per cent of the ration, they are worth almost as much as corn for the young, growing pig. For brood sows, oats can be used to replace up to one-half the grain without reducing the efficiency of the ration very much.

Oats vary in having 75 to 85 per cent the feeding value of corn, depending on the level fed, the quality of the oats (which varies considerably), and the stage of the life cycle of the pig that is being fed. Oats will have the highest replacement value when fed at lower levels. Good-quality, heavy oats contain a small percentage of hulls and thus can be used at higher levels in the ration with better results than light oats. Oats have a lower feeding value on pasture, possibly because the pasture forage is also bulky and fibrous.

Oats should be ground for swine, because it will usually increase their feeding value considerably. A fine or medium grind is better than a coarse grind. Many swine producers prefer to use rolled or crimped oats. If fed as the major part of the ration, oats tend to produce fat which is a little softer than that produced with corn. For best results, it is best to mix oats with other grains for swine.

It takes from 155 to 165 pounds of whole oats to produce 100 pounds of hulled oats. These oats have the hulls removed and 100 pounds of them are equal to about 140 pounds of corn in feeding value. Hulled oats are particularly valuable in rations for very young pigs.

7.2c Wheat

Wheat has approximately 3 to 6 per cent more feeding value than corn. It is generally too high in price, however, to be fed to hogs, since it is produced primarily for human consumption. Low-quality wheat not suitable for milling, as well as damaged wheat, is used for swine feeding. Wheat is more palatable than corn for pigs. It has been shown that pigs self-fed wheat and corn separately, free-choice, eat considerably more of the wheat than corn.

Wheat can be fed whole in self-feeders, but many feeders prefer to coarsely grind it especially with varieties of wheat which produce the smaller and harder grains Wheat should always be ground when it is hand-fed, since the pigs are so eager to get their share they fail to chew it properly Wheat should not be ground too finely, since it will form a pasty mass in the mouth

Wheat generally gives excellent results when fed as the only grain to swine Occasionally, however, pigs may show a tendency to go off feed easier with wheat than with corn Thus, it is recommended that wheat be fed in combination with other grains for best results (see Table XXIII) Pigs self-fed wheat and a protein supplement free choice will usually not eat any more of the supplement than they need because the wheat is so palatable

7 2d Barley

This is an excellent feed for swine, producing firm pork of high quality (see Table XXIII) The feeding value of barley is quite variable, owing to its fluctuation in weight per bushel It will average about 90 per cent the feeding value of corn, but certain tests show values somewhat lower than this Barley is almost equal to corn when used to replace about a third of the grain in the ration

Barley should be ground or rolled for swine It is best to grind barley to a medium degree of fineness Hull-less barley has about the same feeding value as wheat Barley that is badly infested with scab, a fungus, is unpalatable and produces harmful effects if it comprises more than 10 per cent of the ration To be on the safe side, it should not be fed to pregnant sows or to very young pigs

Pigs self-fed barley and a protein supplement, free-choice, will usually consume more of the protein supplement than is needed to balance the ration This is because barley is less palatable than corn

7.2e Rye

Rye is not so palatable as the other grains and for best results should be fed in combination with other palatable grains (see Table XXIII). It should usually be fed at a level of 10 to 20 per cent of the grain mixture and limited to no more than one-half of the grain ration. Rye gives its best results when fed to fattening pigs on pasture in amounts no larger than 20 per cent of the ration. Information on the value of rye varies considerably. When high-quality rye is used and is fed properly, it has about 90 per cent the feeding value of corn, or about the same as barley.

Rye kernels are small and hard and thus should be ground. Rye is frequently contaminated with a fungus called ergot. The ergot makes the rye even more unpalatable. It may also cause abortion and lactation failure and thus should not be fed to pregnant or lactating sows. Likewise, ergot should not be fed in the rations of very young pigs.

7.2f Grain Sorghums

The grain sorghums, of which there are many, have a feeding value of about 90 per cent of corn, although this value will vary from 85 to 95 per cent depending on the sorghum being used (see Table XXIII). Sorghums produce pork equal to that of corn in quality.

The sorghums should be threshed instead of being fed in the head for swine. In most cases the sorghums should be ground. Especially this should be the case with hand feeding. Some of the sorghums are not so palatable as others because of the differences in the amount of tannin in the seed and sometimes are slightly less palatable than corn. All the grain sorghums, even the yellow-seeded ones, are deficient in carotene.

7.2g Rice

Rice kernels are very hard and are enclosed in hard hulls. The rough rice, from which the hull has not been removed,

has about the same fiber level as oats For fattening pigs, the ground rough rice has about 85 per cent the feeding value of corn For best results, the rough rice should be finely ground and fed at a level of 25 to 50 per cent of the grain in the ration Ground rough rice produces good-quality, firm pork

7 2h By-product Feeds from Grains

1 *Hominy feed* is a by product of manufacturing corn meal for human use It consists of a mixture of corn germ, corn bran, and a part of the starchy portion of the kernels Hominy feed resembles ground corn in composition, and its feeding value approximates 95 to 100 per cent that of corn for swine Hominy feed is a satisfactory substitute for corn but it tends to produce soft pork Thus, it is recommended that it replace not more than 50 per cent of the corn in fattening rations and preferably be used at levels of 20 to 25 per cent of the ration (see Table XXIII)

2 *Corn gluten meal* This feed consists chiefly of the corn gluten which is a by-product of corn starch manufacture It may include corn solubles and occasionally some corn oil meal It contains about 42 per cent protein but it is of poor quality and thus should not be used as the main protein supplement for swine feeding It can be used as part of the protein supplement and in combination with supplements which supply the amino acids the corn gluten meal lacks (see Table XXIII) Better results have been obtained when corn gluten meal was fed on pasture rather than in dry lot

3 *Corn gluten feed* This consists of corn gluten meal and corn bran and may or may not contain corn solubles It has about 22 per cent protein, which is of poor quality Gluten feed is not usually fed to swine, since it has more feeding value for cattle It is bulky and not too palatable for swine, although they will eat readily rations containing about 15 per cent of corn gluten feed

4 *Wheat standard middlings brown shorts* This feed is made up mostly of fine particles of bran and germ with a little of the

wheat red dog and contains about 16 per cent protein. It is a very good hog feed. It has about 85 to 95 per cent the feeding value of corn, depending on the level used in the ration. Usually fed at a level of 15 to 25 per cent in the ration, it can be used at higher levels (see Table XXIII).

5. *Wheat flour middlings: wheat gray shorts.* This consists of standard middlings and wheat red dog. It contains about 16 per cent protein but is higher in digestible nutrients than standard middlings. It has about 3 per cent more feeding value than corn when fed at a level of 20 per cent of the ration for growing-fattening pigs (see Table XXIII).

6. *Wheat red dog: wheat white shorts.* This is a feed which consists chiefly of the aleurone layer, with small quantities of flour and fine bran particles. It contains about 16 per cent protein and is worth about 15 per cent more than corn when limited to 15 to 20 per cent of the ration (see Table XXIII). It is used in rations for young pigs because of its high digestibility and lower fiber content.

7. *Wheat bran.* Too bulky for extensive use for growing-fattening pigs, this feed can be used at very low levels of around 5 per cent (see Table XXIII). It can be used to good advantage at levels of 10 to 25 per cent of the ration for brood sows, especially during gestation and before and after farrowing. It is valuable in those rations because of its bulk and laxative effect.

8. *Wheat mixed feed (or "mill run").* This consists of wheat bran and flour middlings or gray shorts. It has about the same feeding value and can be used in the same manner as wheat bran.

9. *Rice bran.* This feed contains rice bran and germs removed in milling rice for human food. It has about 12 per cent protein and 12 per cent fat. Because of the high fat content, it often turns rancid in storage. Rice bran has about the same feeding value as corn if used at a level of not more than 30 per cent of the ration. When used at higher levels its relative feeding value decreases and it tends to produce soft pork. It also is apt to cause scouring with pigs under 75 pounds in weight.

10 Rice polishings This feed consists of the finely powdered material obtained in polishing the kernels after the hulls and bran have been removed It has about the same protein and fat as rice bran but only about one-fourth as much fiber It tends to become rancid on storage and thus should be used as fresh as possible Rice polishings have about 20 per cent more feeding value than corn when limited to about 30 per cent of the corn in the ration If this feed is used at higher levels, its relative feeding value decreases and soft pork will be produced if it makes up more than 50 per cent of the ration It is apt to cause scouring when fed to pigs under 75 pounds in weight

11 Brewers' rice This consists of the small, broken kernels which are removed in the milling process The carcasses of pigs fed brewers' rice are hard and firm Best results are obtained when it is ground and mixed with more palatable feeds It has about the same feeding value as corn

12 Rice meal This consists of ground brown rice and is sometimes used for ground rice after the hull has been removed It has about the same feeding value as corn and produces hard pork

7 3 SELECTING PROTEIN SUPPLEMENTS

Protein supplements should be selected on the basis of their quantity of protein and balance of essential amino acids and their value in correcting protein deficiencies in the energy feeds used in swine rations Consideration also must be given to the cost of the supplement per unit of protein Also the mineral and vitamin content of the protein supplements should be evaluated In general, the cereal grains will average 8 to 12 per cent protein and thus will meet from one-half to about two-thirds of the protein needs of the pig The remainder of the protein needs to come from supplements and pasture See Table V for the amino acid content and Table XX for the analyses of the various protein supplements

TABLE XXII. Estimated Feeds Used by Livestock in the United States in 1954–55 Feed Year[a]

	Tons(thousands)
Oilseed proteins	
Soybean cake and meal	5,600
Cottonseed cake and meal	2,425
Linseed cake and meal	550
Copra cake and meal	190
Peanut cake and meal	20
Animal proteins[b]	
Tankage and meat scraps	1,100
Fish meal	325
Dry milk products	135
Other milk products	1,235
Grain proteins[b]	
Gluten feed and meal	950
Distillers' dried grains	240
Brewers' dried grains	225
Grains	
Corn	61,650
Oats	20,320
Barley	4,221
Grain sorghums	2,755
Wheat and rye	3,000
Low-protein by-products	8,700
Other feeds	
Alfalfa meal	1,200

[a] Adapted from U.S D.A. Feed Situation by Dr. L. C. Cunningham, Cornell University, and presented at 1955 Feed Survey Committee Meeting in Chicago Feed year begins and ends in October. Swine used an estimated 46,914,000 tons of grains and Mill Feeds and 3,273,000 tons of high-protein feeds during 1954–55 feed year.

[b] Converted to oilseed meal equivalent.

7.4 RELATIVE VALUE OF PROTEIN SUPPLEMENTS

Table XXII gives the tonnage of the various protein supplements used in the United States during the 1954–1955 feed year. It also gives data on the other feeds used this same year and how much total feed was fed to swine. Tables XXIII, XXVII, XXXI, XXXII, and XXXIV give suggested levels of various protein supplements to use in swine rations.

7.4a Plant Protein Concentrates

More plant protein concentrates than animal protein concentrates are used for swine feeding This means it is important to know how to use them to supply the proper amount and quality of protein in the ration

1 Soybean oil meal This is an excellent source of protein and is the most extensively used protein supplement in swine feeding in the United States It is becoming available in increasing amounts yearly Properly processed soybean oil meal by the expeller, hydraulic, or solvent method has about the same feeding value Emphasis should be placed on making sure the meal has been properly heat-treated and processed It is possible that methionine supplementation may be beneficial with improperly processed soybean oil meal but of no help with properly cooked meals (See section 2 6c)

Soybean oil meal protein is of better quality than the other protein-rich plant protein supplements (see Table V) When soybean oil meal is self-fed, free-choice, pigs will often eat more than is needed to balance the ration because it is extremely palatable This can be overcome by mixing the soybean oil meal with less palatable feeds Mix the soybean oil meal with (*1*) 30 to 60 per cent oats or 30 to 60 per cent tankage, meat scraps, or fish meal, (*2*) 25 to 35 per cent alfalfa meal, (*3*) 10 to 15 per cent minerals or various combinations of these feeds at somewhat lower levels than if either one was used alone to lower the palatability of soybean oil meal

Soybean oil meal is satisfactory as the only protein supplement for growing-fattening pigs being fed on high-quality pasture However, it might be beneficial to mix 15 to 25 per cent of high-quality tankage, meat scraps, fish meal (as a source of unidentified factors) with the soybean oil meal (see Tables XXIII and XXXIV) It is likely that this would be especially helpful for gilts and boars being grown out for replacements for the sow herd The animal protein supplements are also apt to be beneficial with growing-fattening pigs and sows being fed in dry lot

11	Hominy feed (yellow)[4]	10-80	10-80	5-20	20-80	20-80	—	Corn substitute
34	*Linseed oil meal*	2.5-5	2.5-5	2.5-5	2-8	2-8	5-25	
50	Meat and bone scraps	2.5-10	2.5-10	1.25-5	1.25-5	1.25-5	5-30	High in *lysine*, low in tryptophan
11	Milo (54 lb./bu.)	25-70	50-70	5-35	50-70	60-80	—	Corn substitute
3	Molasses (11.7 lb./gal.)	2.5-20	2.5-10	2.5-7.5	2.5-10	5-15	2.5-10	Used for energy, better appearance, and harder pellets
12	Oats (32 lb./bu.)	10-30	10-20	0	5-20	5-20	—	
15.5	Oats, rolled (no hulls)	—	—	10-50	5-10	—	—	Good palatability, cost limitation
50	Peanut oil meal	2-12	2-12	2.5-5	4-10	1-10	Not over 15	Low in methionine and lysine. High in niacin and pantothenic acid
12	Rye (56 lb./bu.)	0	0	0	10-50	10-70	—	Lacks palatability
34	Skim milk, dried	0	0	2.5-20	0	0	—	Excellent, but cost limitations
37	Soybeans	Under 15	Under 20	0	Under 10	Under 5 to 150 lb. 0 after 150 lb.		Too much fed too late causes soft pork

Continued

TABLE XXIII (*Continued*)

Per cent protein	Ingredients	Per cent of total ration					Per cent of supplement	Remarks
		Gestation	Lactation	Pig starters	Grower	Growing finishing		
45	Soybean oil meal	10–22	10–22	10–25	10–20	5–16	50–80	Good amino acid make-up. Low in methionine
60	Tankage	2.5–10	2.5–10	2 5–5	1.25–5	1.25–5	5–30	Low in tryptophan and *isoleucine*
10	Wheat (60 lb /bu.)	25–90	25–90	5–35	60–80	70–90	—	Corn substitute
14	Wheat bran	5–30	5–15	0	2.5–5	2.5–5	20 (max.)	Bulky, high fiber, laxative
16	Wheat middlings	5–20	5–20	2.5–5	5–30	5–30	20 (max.)	Corn substitute
16	Wheat, red dog	2.5–15	2.5–15	0	2.5–10	2.5–10	—	
12	Whey, dried	2.5–5	2.5–5	2 5–5	2.5–5	2.5–5	5	Good source of growth factors

[a] *Note:* In using the above figures consideration must be given to ingredients of a similar nature and composition. These recommendations were made by Drs. D. V. Catron and C. C. Culbertson, Iowa Station, in Iowa Agricultural Experiment Station AH666, August, 1954.

[b] Some will recommend a higher level of 10% or more alfalfa for pigs to be kept for replacement purposes.

[c] Low-gossypol cottonseed meals have been used at higher levels and have replaced one-half of the protein supplement used with good results.

[d] To avoid soft pork, it is recommended that hominy feed not replace more than 50% of the corn in fattening rations.

2 *Cottonseed meal* In the United States, cottonseed meal ranks second in tonnage to soybean oil meal among the plant protein concentrates (see Table XXII) Cottonseed meal is used widely in swine rations, but the amount is usually limited to 9 to 10 per cent of the total ration because of the hazard of gossypol poisoning But recent work with low gossypol cottonseed meal has shown that higher levels of cottonseed meal can be fed satisfactorily Cottonseed meal is low in lysine and tryptophan (see Tables V and VII), and feeds high in these two amino acids need to be used in rations containing cottonseed meal to make up for this lack

Gossypol, a pigment found in cottonseed, mentioned above, has prevented the unlimited use of cottonseed meal in swine feeds Cottonseed meal has been fed mostly to ruminants, since swine are susceptible to high levels of gossypol Studies at the Florida Station (27) showed that pigs dying from gossypol toxicity exhibited the following symptoms excessive quantities of fluid in the pleural and peritoneal cavities, flabby and enlarged hearts, congested and edematous lungs, and a general congestion of other organs such as the liver, spleen, and lymph glands The use of iron sulfate (0 25 per cent in the ration) will sometimes counteract the effect of the gossypol, but this procedure will not always work and prevent losses

Recent experiments at Florida (27) and at many other stations have shown that low-gossypol cottonseed meal containing less than 0 04 per cent of free gossypol is safe for feeding to swine as the only protein supplement The Florida tests with growing-fattening pigs in dry lot showed that a 50–50 combination of low gossypol cottonseed meal and soybean oil meal was superior to soybean oil meal alone

These results and those at other stations certainly indicate that high-quality, low-gossypol cottonseed meal is a valuable feed for growing-fattening pigs It can be used to excellent advantage in combination with other plant and animal protein concentrates at a level at least as high as 50 per cent of the protein supplement

cake after the removal of part of the oil from ground flaxseed Linseed meal is low in lysine and tryptophan (see Tables V and VII) and feeds high in these amino acids should be used with linseed meal

Pigs fed linseed meal gained at a much slower rate than those fed tankage The difference in rate of gain was less when the pigs were fed on pasture The difference was larger, however, the younger the pigs were when started on experiment Linseed meal does not give as good results as soybean oil meal This would indicate that linseed meal should be used at the lowest level with young pigs, at higher levels with older pigs, and at the highest level with fattening pigs on pasture Linseed meal gives best results when fed at a level of 5 to 25 per cent of the protein supplement used in balancing a ration (see Tables XXXIV and XXIII) Younger pigs would be fed the lower level and larger pigs on pasture toward the higher level High-quality alfalfa meal should be included in supplements containing linseed meal fed in dry lot Linseed meal has been shown to be more satisfactory as a protein supplement when used with wheat or barley rations as compared to corn rations Wheat and barley are higher in lysine and tryptophan than corn (see Table V)

7.4b Animal Protein Concentrates

High-quality animal protein concentrates are excellent sources of protein They are also good sources of vitamins and minerals (see Table XX) and an unidentified factor or factors It is a good policy to include some animal protein supplement in well-balanced rations as is shown in Tables XXVII, XXXI, XXXII, and XXXIV

1 Tankage (or meat meal), meat scraps, meat and bone scraps, and rendering-plant tankage High-grade tankage usually contains 60 per cent protein "Stick," which is the evaporated residue of the tank water, is added back to wet-rendered tankage Sometimes small amounts of dried blood are added to the tankage to raise its protein content to the required level Meat scraps is

A Florida experiment (27) also was conducted to compare soybean meal with low-gossypol cottonseed meal for sows during gestation and lactation when fed on pasture. The results obtained indicated that the two meals were equally valuable. This study would indicate that high-quality, low-gossypol cottonseed meal can be fed to sows as a large part of the protein supplement used.

Future studies will result in more information on the feeding value of low-gossypol cottonseed meals which contain 0.04 per cent or less of free gossypol. Ordinarily processed cottonseed meals should not make up more than 9 to 10 per cent of the ration (see Tables XXIII and XXXIV).

3. Peanut meal. Peanut meal is ground peanut oil cake, the product which remains after the extraction of part of the oil of peanuts by solvents or pressure. Peanut meal tends to become rancid when held too long in warm and moist climates. Thus, it should not be stored for much longer than 5 or 6 weeks in the summer or 8 to 12 weeks during the winter. Peanut meal is low in methionine, lysine, and tryptophan (see Tables V and VII), and feeds high in these amino acids should be fed with peanut meal. Peanut meal is an excellent source of niacin and pantothenic acid (see Table XX).

Peanut meal is so palatable that pigs will eat more than they need to balance their ration when it is self-fed free-choice with corn. This can be alleviated by mixing peanut meal with less palatable feeds such as suggested for soybean oil meal (see above). Florida studies (5) have shown peanut meal to be as valuable as soybean oil meal when fed to weanling pigs on a corn ration supplemented with vitamins and aureomycin. However, we recommend that peanut meal be fed in combination with other plant and animal protein concentrates to pigs being fed in dry lot or to be kept for herd replacement animals (see Tables XXXIV and XXIII). Pigs fed on good pasture, however, which are going to market will make excellent gains with peanut meal as the only protein supplement.

4. Linseed meal. Linseed meal is the finely ground linseed oil

2 Fish meals Fish meals are by-products of the fisheries industry and consist of dried, ground, undecomposed whole fish or fish cuttings or both Commonly used fish meals are menhaden, sardine, or pilchard, herring, salmon, tuna, and white fish meal They range in protein content from 55 to 72 per cent Properly processed fish meal is an excellent protein supplement for swine If fish meal contains too large an amount of fish heads, its feeding value decreases because of the lower nutritive value of the head as compared to the flesh of the fish

Fish meals vary in quality and composition depending on the quality of fish material used and method of processing Most of them, however, are very satisfactory protein supplements for swine

High-quality fish meals are usually superior to tankage and meat scraps for swine feeding Fish meal has given better results than tankage with pigs fed on pasture, but the difference is not so great as for pigs fed in dry lot Good results are obtained by feeding high-quality fish meal as the only protein supplement to grain for pigs and brood sows Because of the usual higher cost of fish meal, however, it is recommended that fish meal be fed at levels of 5 to 30 per cent of protein supplements containing one or more plant protein concentrates plus alfalfa meal (see Tables XXXIV and XXIII) When good-quality fish meal is properly used, it does not produce a fishy flavor in pork

3 Milk products Milk products are excellent feeds The value of most milk products in the human diet makes them too valuable to be used in swine feeding But a certain amount of dried skim milk is being used in pig starter rations, where it has real value Dried whey is also being used in many kinds of swine rations (see Tables XXIII, XXVII, XXXI, XXXII, and XXXIV)

Dried skim milk is too expensive to be used in large amounts in protein supplements for swine It is an excellent feed for pig starters, where it is being used extensively It is an excellent source of protein and B-vitamins and also contains some uniden-

the dry rendered product without added "stick" or blood, and usually contains 55 per cent protein. Meat and bone scraps are meat scraps with added bone, and usually contain 45 to 50 per cent protein. Rendering-plant tankage is a product from small plants which render scrap meat and bones from butcher shops and carcasses of dead animals. It varies considerably in composition, and may contain 35 to 45 per cent protein and a variable amount of bone.

These meat by-products are usually low in tryptophan when fed with corn (see Tables V and VII). The dry rendered meat by-products are somewhat higher in feeding value than those processed by wet-rendering. There is not much difference in feeding value between tankage and meat and bone scraps. Meat scraps, however, are superior in feeding value to tankage as well as meat and bone scraps. In most tests, rendering-plant tankage has been shown to have the lowest feeding value.

Actually, there is considerable variation in the nutritional value of these meat by-products, depending on how much meat and internal organs they contain. The meat packing industry has realized this problem. At present, some effort is being made to produce higher quality tankage, meat scraps, meat and bone scraps, and rendering-plant tankage. Ten or fifteen years ago these meat by-products contained more meat and internal organs; as a result they were a superior nutritional product than many now being produced.

Many experiment stations have not obtained as good results as might be expected when certain of these meat by-products were used in various trials. This has resulted in most of them recommending that tankage, meat scraps, and meat and bone scraps be used at levels of 5 to 30 per cent of the protein supplement containing one or more plant protein concentrates plus alfalfa meal (see Tables XXXIV and XXIII). Many stations, however, will recommend their use at higher levels. Thus, one should pay attention to the quality of these meat by-products and obtain them from firms which are producing high-quality products.

lean or fat of the animals when fed at levels of 5.9 to 13.98 per cent of the ration (21).

5. *Blood meal* contains 80 to 82 per cent protein. It is less digestible and of poorer quality than good-quality tankage for pigs. Most of it is used in commercial calf meals. (See Table XXIII.)

6. *Cheese rind* contains about 60 per cent protein and has about the same feeding value as tankage for the pig (3).

7. *Liver meal* is an excellent source of B-complex vitamins and contains an unidentified factor or factors. It is used at very low levels as a source of these nutrients.

8. *Coconut meal (copra meal)* contains about 21 per cent protein. It has low-quality protein. It has about the same feeding value as corn when it makes up about one-fourth of the ration (24).

9. *Sunflower seed meal* contains about 35 per cent protein. It has not given good results when used as the only protein supplement in swine rations. It is deficient in lysine. Sunflower seed meal can be used as 20 to 30 per cent of the protein supplement for growing-fattening pigs. Preferably, it should be fed to animals that weight 75 to 100 pounds (16,29).

10. *Cull peas* contain about 26 per cent protein and can be used as a grain or protein substitute (20,30). Rations of wheat and barley—supplemented wholly or in part with cull peas and fed to growing-fattening pigs on sudan grass pasture—produced as rapid and efficient gains as rations supplemented with soybean oil meal or meat meal (30).

Cull peas compare very favorably with soybean oil meal and meat meal as a protein supplement for growing-fattening pigs fed in dry lot. The rations used contained wheat, or a mixture of wheat and barley, minerals, and either 5 or 15 per cent alfalfa meal. The pigs fed 15 per cent alfalfa meal during growth performed better during conception, gestation, and lactation. The information obtained indicated that the ration fed during growth has a very important bearing on results obtained later during conception, reproduction, and lactation (10). Cull peas were shown to be a satisfactory protein supplement for

tified factor or factors. It is also a source of lactose, which has been shown to be the best sugar for baby pigs from 1 to 5 weeks of age at the Illinois and Iowa stations. Dried skim milk is very palatable and will be eaten in excess if self-fed. It is a source of higher quality protein than tankage or fish meal.

Dried whey contains 65 to 70 per cent of lactose. It is an excellent source of B-vitamins and is even higher in riboflavin than skim milk. It also contains some unidentified factor or or factors. It is used in many rations at levels of 2 to 3 per cent and sometimes at higher levels.

Liquid skim milk and buttermilk are excellent supplements for farm grain for pigs of all ages. Both have approximately the same feeding value for swine. The small supply available and its bulk, which increases transportation costs, account for the small amount of these two liquid products being used in swine feeding.

Condensed or semisolid buttermilk is an excellent supplement to farm grains for swine. It is more valuable for young pigs than for heavier animals.

7.5 Other Feeds

The following feeds will be discussed very briefly concerning their feeding value for swine. Some of these feeds are used very little whereas others are used considerably.

1. *Fish solubles* are excellent sources of B-complex vitamins. They are used at levels of 1 to 3 per cent in swine rations primarily as a source of vitamins as well as some unidentified factor or factors. (See Tables XXIII and XXXIV.)

2. *Crab meal* is unpalatable to pigs and has not been used successfully in swine feeding (19).

3. *Shrimp meal* contains about 40 per cent protein and is about equal to tankage in feeding value (4).

4. *Shark meal*, which contains about 78 per cent protein, was found to be a satisfactory protein supplement for growing-fattening pigs. It did not produce any off or fishy flavor in the

14 *Beet molasses* is more laxative than cane molasses It is apt to cause scours in pigs unless they are fed limited amounts and are started on it rather gradually Utah studies (23) showed that young pigs weighing 25 to 50 pounds developed a staggering, wobbly gait, performed poorly, and often died when fed a level of 15 per cent beet molasses Hogs weighing over 100 pounds at the start, however, were fed as much as 40 per cent beet molasses without any detrimental effects Newborn pigs, however, were affected with an incoordinate gait and death losses were high if their dams had been fed a 40 per cent beet molasses ration during gestation

TABLE XXIV Level of Cane Molasses to Use in Ration for Growing Fattening Pigs

Weight of pig lb	Level of molasses in ration	
	Range	Probably safe level
40–100	10–15	10
100–150	20 30	20
150–225	40 50	40

The addition of 5 per cent of brewers' yeast or 5 per cent of freshly cut alfalfa (on a dry matter basis) prevented the symptoms in the growing pigs as well as in newly born animals Beet molasses can be used at approximately the same levels as recommended for cane molasses (see Table XXIV) However the pigs should be carefully observed to make sure they are doing well If not, the level of molasses fed should be decreased until they are

15 *Citrus molasses* has a bitter taste which makes it very unpalatable for the pig Florida studies (8) showed that it takes the pig 3 to 7 days to get used to the taste of citrus molasses in the feed mixture After that, the pig will consume the mixed ration containing citrus molasses Because of the bitter taste it has been found necessary to mix citrus molasses with other feeds for pigs to consume it readily

sows when fed with wheat-barley rations containing 20 per cent alfalfa meal (6).

11. Cull beans are frequently fed to swine. They should be cooked, since this improves their feeding value and palatability for swine. A good-quality protein supplement should be fed along with the cooked beans. They can replace from 1/4 to 2/3 of the corn in fattening rations and will most likely give their best results with 75- to 100-pound pigs being fattened out for market.

12. Velvet beans contain dihydroxyphenylalanine, which is closely related to adrenalin, and which is toxic for the pig. Velvet beans also cause diarrhea and vomiting. The toxicity of the beans is partly reduced by cooking them, which makes them more digestible and palatable. Even then, however, they are not a satisfactory hog feed.

Velvet beans can be used with fair results if they do not form over one-fourth of the ration and if a high-quality protein supplement is fed also. Velvet bean pasture is not recommended for swine. Pigs will not do well if they follow cattle fed heavily on velvet beans unless they also get considerable other feed as part of their ration. If used, velvet beans should be fed in small amounts only to heavier pigs, and not to brood sows.

13. Cane molasses is an excellent feed for swine when used properly. The results obtained have varied considerably, depending on the level of molasses used, the ration fed, and the size of the pigs when started on the molasses ration. Molasses has its highest value when used at a low level of up to 10 per cent of the ration. The higher the level used, the lower becomes the feeding value of molasses as compared to grain. When the price of molasses warrants it, the levels shown in Table XXIV can be used in swine fattening rations.

These recommended levels are based on the fact that the heavier pigs can use higher levels of molasses more effectively than smaller animals. These levels might be varied somewhat depending on the ration used, method of feeding, price of molasses and grain, and other factors

lot The results obtained indicated that as much as 5 per cent citrus meal can be satisfactorily fed to young pigs (26)

19 Citrus pulp is a bulky feed Two Florida trials have shown 20 per cent of citrus pulp in the ration to be unsatisfactory for growing-fattening pigs In one of these trials, dried grapefruit pulp replaced corn at a level of 5, 10, and 20 per cent Gains and feed requirements were similar when 5 per cent of grapefruit pulp was substituted for corn although care had to be taken to avoid digestive disturbances Feeding more than 5 per cent of grapefruit pulp, however, caused frequent digestive disturbances, decreased the rate of gain and increased feed requirements (15)

20 Citrus seed meal is a by-product of citrus seed from which the oil has been extracted It contains approximately 35 per cent protein and is a valuable cattle feed

A Florida trial (13) showed the citrus seed meal to be harmful to the pig when fed at levels of 10 and 25 per cent of the ration It caused rough haircoats and unthrifty pigs Citrus seed meal is unpalatable and caused a markedly reduced feed intake by the pig It also caused a decreased rate of gain and increased feed requirement per pound of gain

Thus, citrus seed meal is a good feed for cattle but is harmful for the pig and should not be used in swine rations

21 Cull citrus fruit can be eaten by pigs They will eat tangerines and oranges in preference to grapefruit when these are fed free-choice They consume the juice, seeds, and rag of the fresh citrus (15) Cull tangerines were studied in a later Florida trial (7) Pigs fed cull tangerines alone plus minerals made practically no gain in weight, although they increased in body size at the expense of condition Good results were obtained when the cull tangerines were self-fed, free-choice, with a trio mixture (peanut meal, meat scraps, and alfalfa meal) and minerals

22 Yeast, when irradiated, is used as a source of vitamin D In the northern states, a source of vitamin D is warranted in swine rations during the winter months Dried brewers' yeast

Very little difference was found in the feeding value between citrus and cane molasses for growing-fattening pigs. Citrus molasses can be fed at approximately the same levels as recommended for cane molasses (see Table XXIV). However, a certain amount of extra effort will be required to get the pigs started consuming the feed mixture owing to the bitter taste of the citrus molasses. Most livestock men in Florida feed the citrus molasses to beef cattle instead of hogs, since cattle do not object to the bitter taste of the molasses.

16. Irish potatoes. Only cull or surplus potatoes are fed to livestock in the United States. Raw potatoes produce poor results when fed to swine and thus need to be cooked. It is best to add salt to the water in which the potatoes are cooked to increase their palatability. This water should be discarded, as it is not palatable.

Potatoes should be used at a level of three to four parts of potatoes to one part of grain in a well-balanced ration. At this level, 350 to 450 pounds of potatoes will be equal to 100 pounds of corn in feeding value. Dehydrated potatoes were equal to corn in feeding value when limited to one-third of the ration for pigs on rape pasture.

17. Sweet Potatoes are grown chiefly for human food, but many of the culls are fed to swine. Hogging-off sweet potatoes gives good results, but the cost of production makes this an uneconomical practice. Cooking sweet potatoes improves their feeding value. Better results are obtained when they are fed to older pigs, since they are somewhat bulky for small pigs.

Best results are obtained when they replace 40 to 50 per cent of the grain in a well-balanced ration. When fed properly, it takes 4 to 5 pounds of sweet potatoes to replace a pound of corn in a well-balanced ration. Dehydrated sweet potatoes have approximately 90 per cent the feeding value of corn when used at a level of one-third to two-thirds of a well-balanced ration.

18. Citrus meal is the finer particles of dried citrus pulp. Levels of 0.5, 2.0, and 5.0 per cent of citrus meal were incorporated into a corn-soybean ration and fed to weanling pigs in dry

pigs which have been fed peanuts for any length of time It may take 3 to 3 5 times or more gain on a hardening ration as compared to the gain on peanuts to produce hard or medium-hard hog carcasses This means that 40 pounds of gain on peanuts would probably require 120 to 140 pounds of gain on a hardening ration

Fig 41 Note effect of soft pork on bacon which is in proportion to the amount of gain made on peanuts The pigs in lot V were fed a corn soybean meal ration The pigs in lots I, II, III and IV made 145, 111, 98, and 71 pounds of gain on peanuts, respectively (Courtesy A Z Palmer Florida Agricultural Experiment Station)

A recent Florida study (1,2) showed that 50-pound pigs fed peanuts to 122, 151, and 165 pound weights and then fed hardening rations until they weighed approximately 200 pounds still produced carcasses which graded soft These groups had 111 3 pounds of "soft" gain and 27 7 pounds of "hard" gain in group I, 98 3 pounds of "soft" and 51 5 pounds of "hard" in group II, and 71 5 pounds of "hard" and 101 0 pounds of "soft" gain in group III Peanut feeding tended to yield carcasses with more back-fat thickness in relation to carcass length and thus caused lower carcass grades

is an excellent source of B-complex vitamins. Usually it is used at levels of 2 to 5 per cent of the ration in supplying B vitamins. Dried brewers' yeast contains almost 50 per cent protein, but it is too expensive to be used as a source of protein in swine rations (22).

23. *Distillers' dried solubles* are most valuable as a source of B-complex vitamins in swine rations. The protein of distillers' solubles is of poor quality, since it is deficient in lysine and tryptophan, in which corn is also deficient. However, it can be used to replace some of the protein supplement in a trio mix or mixed supplement. (See Tables XXIII and XXXIV.) It is less satisfactory as a substitute for alfalfa meal in a trio mix. It also has been of less value when added to a ration containing high-quality alfalfa meal. The more alfalfa in the ration, and the higher quality it is, the less is the beneficial effect of adding distillers' solubles to the ration (14,17).

24. *Distillers' dried grains* vary considerably in composition because of the various types of distillers' dried grains available. They are ordinarily not fed to swine since they are much better suited for feeding cattle.

25. *Oat mill feed* is a bulky feed high in fiber and low in total digestible nutrients. If used in swine rations, it should be fed at levels of 5 or 10 per cent and no higher than 15 per cent of the ration. At the 15 per cent level it would have 1/4 to 1/3 the feeding value of corn for fattening pigs.

26. *Oat hulls* have very little feeding value for swine. They are high in fiber and low in total digestible nutrients.

27. *Peanuts* are palatable and an excellent feed for swine. A considerable acreage of peanuts is hogged-off in the southern states. Peanuts are lacking in calcium and salt and will give excellent results if these minerals are supplied along with green forage. Adequate experimental information is not available, but it is thought that a small amount of high-quality tankage or fish meal would benefit pigs fed peanuts.

Pigs fed peanuts produce soft pork. Studies conducted to date show that it takes a considerable length of time to harden

gain Levels in excess of 10 per cent may be used, however, if rate of gain is not an important consideration and if the cost of gains is reduced Moreover, experimental work has shown that pigs fed 15 per cent alfalfa meal during growth stored some unidentified factor or factors which later caused them to conceive faster and to reproduce and lactate more satisfactorily than sows which had been fed only 5 per cent of alfalfa during growth (9 10)

During gestation and lactation, sows can be fed from 8 to 20 per cent or more of alfalfa meal in the ration (see Table XXIII) The level to use will depend on the other feeds in the ration and their nutritional adequacy Many experiments have shown that 5 per cent of alfalfa meal is not adequate in certain brood sow rations and that using higher levels of 10 to 15 per cent alfalfa was of considerable benefit (9,10,11,18,25)

The use of high-quality dehydrated alfalfa meal with pigs fed in dry lot is a means of substituting for pasture It is the closest substitute available for pasture and thus insures pigs of most of the nutritional value of pasture

31 Other hays There is not much information available on the feeding value of other hays for swine feeding High-quality soybean, lespedeza, kudza, red clover, cowpea, sudan grass, and other hays may be used in swine feeding These hays would be worth somewhat less than alfalfa in swine rations but might be satisfactory under many conditions

32 Silage Very little information is available on feeding silage for growing-fattening pigs Considerable experimental work is now under way on feeding silage to sows Silage will undoubtedly be used in sow rations in the future As more information is obtained, the role of silage in sow rations will become clearer Recommendations on feeding silage to sows will be given in Chapter IX

33 Tung nut meal is unpalatable to pigs They refused to consume mixtures containing 30 to 50 per cent of detoxified tung nut meal in combination with soybean oil meal When the tung nut meal was reduced to 5, 10, or 15 per cent of the protein

More studies are needed on this problem especially to determine whether any special feed ingredients might be used to harden the pork of peanut-fed pigs.

28. Soybeans are usually more profitable when harvested rather than when hogged-down. Soybeans produce soft pork and also the raw soybean is lower in feeding value than well-cooked soybeans or soybean oil meal. Raw soybeans do not give good results when used as the only protein supplement for brood sows or for young pigs. They give better results with well-grown pigs and are more satisfactory on pasture than in dry lot.

If pigs are used to hog-down a field of raw soybeans, they will make good gains if they are fed a mineral mixture and a limited amount of corn as well. The carcasses, however, will be soft. They can be hardened by a period of feeding on a hardening ration. This period will be less than with peanuts, but will vary, depending on the weight of the pigs when started on soybeans, the length of time they are fed, and the other feeds used.

29. Chufas produce a tuber which remains in the ground and is hogged-off in some sections of the South. Chufas are low in protein and thus should be supplemented with a good protein supplement and minerals. They produce soft pork which can be hardened by feeding a hardening ration for an adequate period of time.

30. Alfalfa meal is the most widely used of the legume meals for swine feeding. It is an excellent source of carotene and the known B-complex vitamins. It also contains an unidentified factor or factors which is of value for pigs and sows fed under dry-lot conditions.

Swine fed in dry lot should have alfalfa meal in the ration. Growing-fattening pigs should have at least 2.5 to 5 per cent dehydrated alfalfa meal in the ration. (See Tables XXIII and XXXIV.) With some rations, this level can be increased up to 10 per cent without affecting rate of gain or efficiency of feed utilization.

Levels of 15 per cent alfalfa meal in the ration usually tend to slow rate of gain and increase feed requirement per pound of

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28 Wallace, H D, and L Gillespie, *Florida Agr Expt Sta A H Mimeo Series* No 55-3 (1955)
29 Wallace, H D, M Milicevic, and D Kropf, *Florida Agr Expt Sta A H Mimeo* No 4 (1953)
30 Warwick, E J, T J Cunha, and M E Ensminger, *Washington Agr Expt Sta Bull* 500 (1948)

mixture, limited consumption occurred. Consumption, however, appeared to be less than required for optimum gains (28).

34. Fresh avocado pulp, in which the fruit was halved and the seeds removed, was fed to 60-pound growing-fattening pigs. Good gains were obtained. The pigs liked the pulp very well and consumed an average of 7.15 pounds (wastage included) of it per day in addition to 2.48 pounds of the control concentrate ration. It took 9.64 pounds of the avocado pulp to replace 1 pound of the control corn-soybean oil meal ration. Avocado pulp fed alone gave poor results. The avocado seed was extremely unpalatable to the pig. A pig offered avocado seed only refused to eat them for a period of 1 week even though no other feed was available (12).

35. Feather meal and poultry meat meal. A recent Florida study by Combs and Wallace showed that feather meal and poultry meat meal were satisfactory sources of protein for growing-fattening pigs. The gains and feed efficiency of pigs that received rations containing 5 per cent feather meal, or 8.5 or 16 per cent poultry meat meal, were comparable to those of pigs fed a soybean oil meal ration. More studies are still needed on both these products before they can be recommended for swine feeding.

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CHAPTER VIII

Feeding Pigs during Various Stages of Growth

8 0 INTRODUCTION

Developments in feeding pigs have been very rapid during the last few years The introduction of antibiotics in early 1950 started a new era in the nutrition of the very young pig Before that time, very little work had been done on the nutritional requirements of the newly born pig With the use of antibiotics, it became possible to wean pigs shortly after farrowing, this led to studies on early weaning of pigs

Thus, feeding of pigs has advanced to the point where the the growth period is divided into several segments and the pig is fed according to what stage of the growth cycle it is in The younger the pig, the more critical the period becomes Consequently higher quality and more highly fortified rations are needed These feeding periods will be discussed in detail in this chapter

8 1 SOW'S RATION AFFECTS PIG'S GROWTH

The ration the sow receives during her growing period, as well as during gestation, will definitely affect the ability of the baby pigs to survive and grow after weaning (7,8,12) This means that gilts kept for reproduction must be fed well-balanced rations during their growing period to develop the normal reproductive tract which is needed for successful production of large litters A high-quality ration needs to be fed to the sow during gestation to insure proper growth and development of the young in the uterus One of the biggest mistakes swine producers make is to start feeding a sow a well-balanced ration only 3 or 4 weeks before she is due to farrow They have heard that the developing

pigs. Such pigs not only will have a better chance to survive but also will be heavier at weaning.

These pigs which are heavier at weaning also tend to do better afterwards. A comprehensive study at the Minnesota Station (18)—involving 745 gilt litters, composed of 5562 pigs born alive, of which 3918 pigs survived to weaning—also showed that the average birth weight had the greatest effect, of the factors studied, upon both survival and total weaning weight of the litters.

8.2 EARLY WEANING OF PIGS

8.2a Synthetic Milk

An early attempt (4) to feed a synthetic milk and thus wean pigs right after birth was unsuccessful because sucrose was fed as the source of carbohydrate and because antibiotics were not being used then. Later, Illinois workers showed that the newborn pig cannot utilize sucrose (1,2,11); this partly accounted for the early failure. The development of antibiotics, however, was the main factor in the development of synthetic milks and in their ability to support the growth of pigs which were weaned about 48 hours after birth. Shortly after the development of such synthetic milks in 1951, pig hatcheries sprang up in many sections of the country. These pig hatcheries were establishments which specialized in producing and selling weanling pigs throughout the year for growing and fattening on the farms of purchasers. The hatcheries ranged in scale of operation from 40 or 50 sows on up to 400 or more.

The pig hatchery, however, was characterized by many failures and few successes. Disease, lack of sanitation, poor management, and other factors were the chief causes of the failures. Synthetic milks were not widely accepted. Liquid milk often spilled over, and soaked the litter on the floor. This, in turn, chilled the pigs, caused scouring, etc. Also, keeping the equipment clean and sanitary provided many problems; many cases of scours and deaths resulted from unsanitary equipment. Souring

fetuses make most of their growth during this period (*which* is true). As a result they feed the sow a well-balanced ration only then. Until that time, they feed the sow poor-quality rations in an effort to save on feed. As a result, the sow does not obtain the nutrients she needs and so farrows many weak or dead pigs and ends up weaning small, poor-looking litters. The

Fig. 42. Weak, unthrifty looking pigs are the result of poor feeding. These pigs' mothers were fed a ration inadequate in vitamins. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

answer to this problem is never to deprive the sow of needed protein, minerals, and vitamins at any time. Any lack of these nutrients in the ration means a loss of pigs—and these lost pigs never get to market.

The information in Table XXV from the Iowa Station shows that the heavier the pig is at birth the heavier it will be at weaning. On the average, a difference of 1 pound in weight at birth was accompanied by 7.78 pounds difference at weaning (9). This is in good agreement with studies at the Missouri Station (17). This information shows the value of properly feeding the sow during gestation so that she will farrow heavy, thrifty

of the milk in the feeders was particularly troublesome when the pigs did not promptly clean up their feed As a result, only a few of the hatcheries—those with qualified personnel and with good management procedures—were able to raise pigs successfully under this system

Before long, the emphasis was shifted to dry meal formulations and away from liquid milk Much work is now under way to formulate dry pre-starter and starter feeds which can be used as a substitute for sow's milk and thus allow early weaning of pigs

Table XXVI shows information obtained at the Wisconsin Station (3) on the constituents of colostrum and milk from sows milked at the time of parturition, the third day, the end of the first week, and each subsequent week throughout an 8-week lactation period The third to fourth week seems to be the period when there is a change in some of the constituents of sow's milk This is also the period of time when the sow's milk secretion starts to decrease The information in Table XXVI can serve as a guide to those studying milk replacement feeds for early weaned pigs

8 2b How Early Should Pigs Be Weaned?

The trend in swine production is toward early weaning of pigs, this practice is becoming increasingly popular Many swine producers are already weaning their pigs at 6 weeks instead of the customary 8 weeks of age by the use of high-quality starter feeds Moreover, many are considering weaning their pigs earlier—as early as 3 weeks of age This is as early as many authorities feel they should be weaned on the farm at the present time

Undoubtedly, there are a few swine producers who have the know-how and facilities for raising pigs that are weaned at less than 3 weeks of age The majority, however, should wean at 3 weeks or more of age Farmers with only average management ability and facilities should wait until the pigs are about 5 to 6 weeks old before weaning The earlier the swine producer weans his pigs, the more know-how, facilities, and well-

TABLE XXV. Average Birth and Weekly Weights of Suckling Pigs Classified According to Birth Weight at the Iowa Station[a] (9)

Weight range (lb)	<1.76	1.76–2.00	2.01–2.25	2.26–2.50	2.51–2.75	2.76–3.00	3.01–3.25	3.26–3.50	3.51–3.75	>3.75
Birth	1.5	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9
1 week	3.1	3.5	4.0	4.5	4.6	5.1	5.6	5.9	6.3	6.6
2 weeks	5.0	5.7	6.4	7.2	7.3	7.9	8.6	8.9	9.6	10.0
3 weeks	6.8	7.7	9.1	10.0	10.0	10.8	11.8	12.1	12.8	13.6
4 weeks	8.5	9.7	11.6	12.6	12.6	13.5	14.6	15.0	16.1	17.2
5 weeks	10.2	11.6	13.6	14.9	15.1	15.9	17.5	18.2	19.2	20.9
6 weeks	11.7	13.7	16.0	17.7	18.0	19.0	21.0	22.1	22.9	25.1
7 weeks	14.0	16.5	19.1	21.4	21.8	23.0	25.5	27.1	27.5	30.6
8 weeks	17.1	20.0	23.3	26.2	26.5	28.1	31.2	32.8	33.5	37.3

[a] Based on data obtained from 1296 Duroc pigs from 191 litters. Pigs which died prior to weaning were not included *in the study.*

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Birth	1.5	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9
1 week	3.1	3.5	4.0	4.5	4.6	5.1	5.6	5.9	6.3	6.6
2 weeks	5.0	5.7	6.4	7.2	7.3	7.9	8.6	8.9	9.6	10.0
3 weeks	6.8	7.7	9.1	10.0	10.0	10.8	11.8	12.1	12.8	13.6
4 weeks	8.5	9.7	11.6	12.6	12.6	13.5	14.6	15.0	16.1	17.2
5 weeks	10.2	11.6	13.6	14.9	15.1	15.9	17.5	18.2	19.2	20.9
6 weeks	11.7	13.7	16.0	17.7	18.0	19.0	21.0	22.1	22.9	25.1
7 weeks	14.0	16.5	19.1	21.4	21.8	23.0	25.5	27.1	27.5	30.6
8 weeks	17.1	20.0	23.3	26.2	26.5	28.1	31.2	32.8	33.5	37.3

[a] Based on data obtained from 1296 Duroc pigs from 191 litters. Pigs which died prior to weaning were not included in the study.

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TABLE XXVI. Lactational Trend of the Milk Constituents Studied with Sows at Wisconsin Station (3)

Constituent	Lot	Total No. of samples	Period in lactation										Avg. 1-8 wk.
			1 day[a]	3 day	1 wk	2 wk	3 wk	4 wk	5 wk.	6 wk.	7 wk.	8 wk.	
Total solids, %	Pasture	66	22.81	22.41	20.63	20.11	18.98	19.39	17.56	19.55	19.23	20.34	19.47
	Dry lot	67	22.81	26.23	21.93	20.67	19.82	20.49	20.46	20.74	20.18	20.44	20.69
Solids-not-fat, %	Pasture	66	15.92	12.83	12.48	13.04	12.71	12.99	12.44	13.98	13.66	14.32	13.16
	Dry lot	67	17.21	12.81	13.69	12.71	12.43	13.14	13.57	13.65	14.24	13.89	13.38
Protein, %	Pasture	39	11.25	8.95	7.10	6.90	6.14	7.45	6.10	6.67	8.19	8.30	7.09
	Dry lot	32	14.29	8.23	7.61	6.83	6.16	8.17	7.18	8.23	7.85	7.37	7.42
Lactose, %	Pasture	39	2.89	4.99	4.35	5.33	6.12	3.93	5.58	6.06	4.55	4.77	5.18
	Dry lot	32	3.42	3.56	5.43	4.95	4.79	4.23	5.79	5.32	4.60	5.54	5.08
	Pasture	67	0.72	0.83	0.86	0.79	0.85	1.03	1.04	1.08	1.09	1.30	0.99
Ash %	Dry lot	67	0.73	0.94	0.83	0.79	0.90	0.90	0.99	1.08	1.14	1.22	0.98

[a] Colostrum milk sampled at time of parturition.

trained personnel will be needed to operate successfully The swine producer who lacks these tools and skills should go into the program slowly, and gradually lessen the time pigs are kept on the sow in line with the success he is experiencing

A great deal of research is being conducted on this problem Pigs have been successfully weaned at 2 days of age and even earlier when special techniques were used The research developments in early weaning will undoubtedly make it possible to continuously lower the time the pig will need to stay with the sow In other words, it seems the swine industry is becoming more specialized and that prestarter and starter feeds will increasingly serve as a *substitute for the sow*

8 2c Advantages and Disadvantages of Early Weaning

At the present, among the advantages of early weaning (if done properly) are the following

1 Heavier and more uniform pigs at 8 weeks of age as well as fewer runts This is because the sow reaches maximum milk flow at about 3 weeks after farrowing This peak may occur later in certain sows, but the trend is usually downward by the fourth week Early weaning will mean the pig can obtain more to eat than if it continues to nurse the sow to 8 weeks of age But pre-starter and starter feeds will need to be highly palatable in order to induce the pigs to eat heavily Moreover, they will need to be highly fortified with antibiotics and the needed protein, minerals, and vitamins

2 More pigs raised per litter through reduction in losses and saving of surplus pigs Most pig losses still occur shortly after birth and during the first few days Early weaning will not prevent these losses Only proper feeding of the sow during growth and gestation, together with good management and disease control, will lessen these small pig losses Early weaning, however, will save pigs from being laid on or crippled by the sow It will also save orphan pigs that die when sows die or go dry or become runts when sows have more pigs than they can adequately nurse

3. Complete control of the nutrients in the pre-starter and starter feeds, thus fulfilling the optimum requirements of the young pig. If these feeds are made palatable enough, one can insure that the pigs will eat enough and will get all the carbohydrates, fat, protein, minerals, vitamins, and antibiotics needed for maximum growth and development.

4. Better disease control. Early-weaned pigs have fewer diseases and parasites which are transmitted from the sow to her pigs. Moreover, early-weaned pigs stay healthier and have less anemia and scours. Sow's milk is low in iron and copper, but as much of these two minerals as is needed can be put into the milk substitutes. This will save the trouble of preventing anemia by other means. More diseases, however, can result if good management is not followed with early weaned pigs.

5. Saving on the sow's feed. This occurs since sows usually eat twice as much feed during lactation as in gestation. Against this saving, however, one must figure the cost of the pre-starter and starter feeds the young pigs eat.

6. Sows lose less weight during lactation. This means the sow could be sold soon after farrowing if she was no longer needed or if the market price was favorable then.

7. Sows can be rebred earlier if one wants to produce more litters per year. Most sows will not rebreed and conceive, however, until about 3 weeks after they farrow.

8. Encourages the spread of the farrowing season throughout more of the year. This gives the advantage of more uniform marketing and, as a result, will tend to eliminate some of the highs and lows which occur in hog marketing and prices during the year.

Some of the limitations of early weaning are as follows:

1. Requires highly fortified, well-balanced, and highly palatable pre-starter and starter feeds. Just any feed mixture will not do a successful job of raising early-weaned pigs.

2. Requires excellent management and know-how. Once the pigs are taken away from the sow, they cannot be neglected. The sow can cover up poor management practices, inadequate

rations, and failure to feed and water regularly to a certain extent. She cannot do this, however, once the pigs are taken from her care.

3. Requires better-than-average equipment and excellent sanitation practices. These facilities and practices, however, are usually no better than those already used by most good hog producers.

Undoubtedly there are other advantages and limitations to early weaning. The foregoing however, are among the most important and should be carefully considered by those who plan to enter the program.

8.2d Pre-Starter Feeds

The dry prestarter feeds are a substitute for liquid synthetic milk, but without the disadvantages of the liquid product. Pre-starter feed allows one to wean pigs after they weigh 5 pounds. In such a program the pre-starter feed is fed for about a week, and then the pigs are switched over to a starter feed. However, only hog producers with excellent management ability, facilities, and know-how should attempt to wean pigs at 5 pounds live weight. Dr. D. V. Catron at Iowa State College has been a pioneer in the development of prestarter feeds. He has developed Iowa State College (I.S.C.) Pig Pre-Starter "75," whose original and revised formulas are given in Table XXVII.

A look at the ration shows that it is highly fortified with protein, minerals, vitamins, antibiotics, sources of unidentified factors, and highly palatable energy feeds. It includes trace minerals to prevent anemia. High levels of antibiotics are used to prevent scouring and to promote fast growth. This feed is used at one of the most critical periods in the life cycle of the pig, and this is the reason for such a high-quality ration. Since only 3 to 5 pounds of this feed is usually fed to each pig, the cost is not of much concern so long as it gets the pigs started well. This ration does a good job for the baby pigs weaned at 5 to 10 pounds of body weight. As more research is conducted this ration will undoubtedly become more simplified.

TABLE XXVII. Formula for I.S.C. Pig Pre-Starter "75"

Ingredients	*Orig. formula, lb.*	*Rev. 5-1-57*
Ground yellow corn (fine ground)	—	12.55
Dextrose (corn sugar)	15.0	5.0
Sugar (cane or beet)	5.0	10.0
Toasted corn flakes	8.55	—
Dried skim milk (low heat, spray dried)	40 0	40.0
Dried whey (low lactose)	2.5	—
Dried whey (70% lactose)	—	2.5
50% solvent soybean oil meal	12.1	14.5
60% fish meal (good quality)	2.5	—
Condensed fish solubles (red, sardine or menhaden)	—	2.5
Lard (stabilized)	5.0	5.0
Lecithin	1.0	—
Dried brewers yeast	1.0	1.0
Corn steep water	1.0	1.0
Dried beet pulp	2.0	2.0
Vitamin-antibiotic premix	2.0	2.5
Dicalcium phosphate	1 2	0 6
Calcium carbonate	0 5	0.15
Iodized salt	0 5	0.5
Trade minerals (swine)	0.15	0.2
Total	100.0	100.0

Vitamin-antibiotic premix for formula

	Orig. formula	*Rev. 5-1-57*
Vitamin A (20,000 I.U./g.)	2500.00 g.	550.00 g.
Vitamin D_2 (142-F irrad. yeast)	35.20 g	16.90 g.
Riboflavin	1 60 g.	9.00 g.
Calcium pantothenate	9.50 g.	16.00 g
Niacin	113 66 g.	70.00 g.
Choline chloride (100%)	163 50 g.	—
Vitamin B_{12} (200 mg./lb.)	5.00 lb	4.00 lb
3% folic acid supplement	1500.00 g.	1.20 g.
Alpha tocopherol acetate	50.00 g.	—
Ascorbic acid (vitamin C)	1500.00 g.	—
Thiamine HCl	10 00 g.	—
Pyridoxine	10.00 g.	—
Para-Aminobenzoic acid	40.00 g.	—
Vitamin K (menadione)	5.00 g.	—
Antibiotic(s)	500.00 g.	200.00 g.
Solv. soybean oil meal	(balance)	(balance)
Total	100.00 lb.	100.00 lb.

TABLE XXVII (*Continued*)

Calculated analysis

	Orig formula	Rev 5-1-57
Protein, %	24 0	25 1
Fat, %	7 0	5 8
Fiber, %	1 0	1 2
Calcium, %	1 25	0 8
Phosphorus %	0 85	0 7
Vitamin A, I U /lb	10,000	2846
Vitamin D_2, I U /lb	1,000	600
Riboflavin, mg /lb	5	6 7
Niacin, mg /lb	30	27 6
Choline chloride, mg /lb	500	509
Vitamin B_{12} µg /lb	20	20
Antibiotics, mg /lb	100	50
Pantothenic acid, mg /lb	10	12 7

The following vitamins were also added per pound of ration without crediting the other ingredients for their contribution of these to the ration

Alpha tocopherol, mg /lb	10	—
Folic acid, mg /lb	9 0	—
Ascorbic acid (vitamin C), mg /lb	300	—
Thiamine, mg /lb	2 0	—
Pyridoxine, mg /lb	2 0	—
Para Aminobenzoic acid mg /lb	8 0	—
Vitamin K (menadione), mg /lb	1 0	—

A special dry ration for baby pigs weaned at 5 to 10 lb of body weight This formula is necessarily complex and it must be carefully blended Note that the 7 vitamins shown above in the original formula are left out of the revised formula As more research is conducted, this formula will undoubtedly be changed some more

It does serve, however, as a good starting point in developing pre-starter feed mixtures for the very early weaned pig To date, the meal form of the pre-starter seems to work best

Following are the management suggestions which Dr D V Catron gives (as of May 1, 1957) on early weaning of pigs fed his prestarter ration

"Farrow sows in farrowing stalls and let pigs nurse sows in

stalls for 1 to 3 weeks. This will save heavy pig losses from overlaying and injury. Farrowing stalls make it easier to transplant pigs from one sow to another, thereby equalizing litters. Give each pig an iron pill the third day (and once every week while pigs are nursing sows), then forget about anemia with new pre-starter. Put pre-starter before the pigs the third day while still with the sow. It helps big litters on poor-milking sows. Pigs may he given a shot of hog cholera and/or erysipelas serum at 7 days of age; these may serve as protective booster shots. Early weaned pigs *do not* have to be "partitioned off" (if in same building) or put in a separate building from sows nursing litters—nursing noise does not bother them.

"Pigs may be weaned from sows at 7 to 21 days of age or at a minimum of 5 pounds. *Do not wean pigs at less than 5 pounds* unless necessary. Most good producers may find it best to wait until pigs weigh 10 to 12 pounds (about 2–3 weeks of age) before weaning under their conditions. Weaning weight depends on adequacy of housing and equipment, facilities for keeping pigs warm, disease level and skill of management. Sows are easily dried up for selling or rebreeding. Though sows will come in heat about 3 days after pigs are weaned, good conception usually isn't obtained until 14 to 21 days after farrowing. Since sows do not lose lactation weight, do not put the usual gestation gain on them.

Pre-Starter Period

"Self-feed $3^1/_2$ to 5 pounds of pre-starter per pig. Do not expect pigs to be eating well before the 2nd day after weaning. To teach pigs to eat, show them where feed is located and put a *little in their mouths at about 6, then again at 24 hours after* weaning. One or two pigs ("teacher-pigs"), 2 or 3 days older, which have learned to eat will teach newly weaned pigs to eat readily. It is preferred not to start over 10 pigs per pen. Allow 6 sq. ft. floor space per pig from 1 to 5 weeks. Avoid floor drafts by using solid pen walls. Suspend heat lamps from ceiling *near*

each feeder and provide 80°F. 5 inches above bedding. Lower temperature 5° per week to 60°F. by raising heat lamp, *Keep bedding dry. Provide clean, fresh water in automatic founts; flush founts daily but keep floor dry.*

Starter Period

"Shift to highly fortified sugared starter pellets. Feed 20 to 25 pounds per pig. Do not overcrowd pigs. Allow at least one self-feeder space (4 inches) for each two pigs. Follow your regular immunization program at 5 weeks of age.

Grower Period

"When pigs are 5 weeks old, sort pigs according to size. But do not put more than 20 pigs in one pen Allow at least 8 sq. ft. of floor space per pig if still in confinement. Feed 50 to 55 pounds of grower per pig. After pigs weigh 50 pounds (about 8 weeks old) they are ready for a regular growing-finishing ration.

"If you decide to wean pigs early—you should have good housing, equipment, and management—but *no better than is needed for successful raising of pigs on sows.* Management requirements for early weaning pigs are similar to successful chick brooding

"Baby pigs *must be kept warm and dry.* Use solid wall pen partitions to prevent floor drafts. Provide plenty of feeder space for pre-starter and clean fresh water at all times. Do not overcrowd."

8.2c Starter Feeds

These feeds can be used as (*1*) a follow-up feed to the pre-starter ration for early weaned pigs, or (2) as a creep feed for pigs which are to be weaned at 5 to 6 weeks of age. After about a week, as soon as baby pigs learn to eat the pre-starter, they can be switched to a good starter ration. The starter feed does not have to be so highly fortified as the pre starter and thus will be less expensive. Pelleting of starter feeds will reduce feed wastage. Swine producers who wish to leave their pigs on the sows and

wean at a later age may get their pigs started eating with either the pre-starter or starter ration. If pigs eat a good starter ration early and in large enough quantities to keep them gaining well, it is possible to wean them at 5 to 6 weeks of age. These pigs get the starter self-fed, free-choice in a creep.

Iowa workers (13) have found sugar to be one of the most palatable ingredients to include in pig pre-starter and starter rations. Early Iowa work showed that sugar-coating the starter feed caused the greatest consumption of it. Later experiments there, however, showed that the advantage of sugar-coating was not so evident. Just to have the sugar in the starter feed seems to be the important thing. Illinois workers (15) found

TABLE XXVIII. Choice of Feeds by Suckling Pigs at Illinois Station (15)

Feeds offered	Feed consumed, lb.	Percentage of total eaten[a]
Hulled oats	158 0	43.8
Rolled oats 75%, molasses concentrate[b] 25%	73.5	20.4
Pig starter ration fed in Lot 3, Experiment 2		
Pellets	52.0	14.4
Meal	31.0	8.6
Dry skim milk 75%, molasses concentrate[b] 25%	25.0	6.9
Shelled corn	4.0	1.1
Rolled oats	3.0	0.8
Dry skim milk	3.0	0.8
Meat scraps (55% crude protein)	3.0	0.8
Dry synthetic milk	2.0	0.6
Pig supplement fed in Lot 1, Expts. 1 & 2	2.0	0 6
High-efficiency broiler ration		
Meal	1.0	0 3
Pellets	1 0	0.3
Ground yellow corn	1.0	0.3
Solvent soybean oil meal (44% crude protein)	1.0	0.3
Solvent soybean oil meal (50% crude protein)	0.0	0.0
Total	360.5	100.0

[a] Percentage of total eaten when all these various feeds were placed before pigs to choose from.

[b] Pure cane molasses blended with sugar cane pulp and dried.

that suckling pigs preferred hulled oats to all other feeds studied They also ate mixtures containing molasses in greater quantities than the same feeds with no molasses added (See Table XXVIII) Florida workers (16) found that 10 per cent cane sugar and 10 per cent stabilized beef tallow increased the palatability the most of the creep rations they studied

Table XXIX shows the results obtained in a second Florida trial where various combinations of sugar, lard, and beef tallow were studied In this trial, a ration containing a combination of cane sugar and lard was more acceptable to pigs than a ration containing only cane sugar When fed singly, the order of preference was for lard, cane sugar, and tallow In both experiments, the pigs at first showed a preference for the rations containing waste fat As the pigs grew older, however, they consumed an ever-increasing amount of the sugar rations

TABLE XXIX Effect of Feeds on Palatability of Creep Rations at Florida Station (16)

Per cent added to ration[a]	Per cent of total feed[b]
5% stabilized lard + 5% cane sugar	30 3
10% stabilized lard	24 8
10% cane sugar	14 7
5% stabilized beef tallow + 5% cane sugar	12 5
5% stabilized beef tallow + 5% stabilized lard	11 5
10% stabilized beef tallow	6 3

[a] All rations were pelleted The ration was compounded of ground yellow corn ground rolled oats, soybean oil meal, dried skim milk, bone meal, limestone, trace mineralized salt, plus fortification with aureomycin riboflavin, niacin, pantothenic acid, choline, B_{12} and vitamin A

[b] Per cent of total feed consumed by pigs when all these various feeds were placed before them to choose from

Table XXX shows data obtained at Illinois which indicated that pigs ate more starter as the sugar content was increased on up to 20 per cent of the ration They also found that dried skim milk is a highly palatable feed in a pig starter, but that saccharin

TABLE XXX. Palatability of Starter Rations for Suckling Pigs (10)

Ration	Average % of total starter consumed*	
	Meal	Pellets
20% cane sugar	38	37
15% cane sugar	20	16
High level of dried skim milk	17	29
10% cane sugar	13	9
5% cane sugar	5	3
0 05% saccharin	4	4
0% cane sugar	2	1

* Average per cent of total starter consumed when all feeds were placed before pigs to choose from.

The ration consisted of rolled oats, ground yellow corn, soybean oil meal, dried skim milk, condensed fish solubles, crude corn oil, plus vitamin and mineral supplements.

is not of much value in increasing the palatability of the starter feed.

This information shows there is yet much to learn concerning the palatability of feeds for pre-starter and starter rations. More experimental work on this subject is needed, since palatability is one of the most important items to consider in formulating these rations.

Table XXXI gives the pre-starter and starter rations recommended for suckling pigs by the Illinois Station (14) in 1954. Table XXXII gives a starter ration recommended by the Iowa Station (13) in 1953. By studying the rations recommended by both experiment stations, one can find considerable difference in the feeds used and the amount of vitamin and antibiotic supplementation included. These differences are due to the fact that this is a very new field, and not much information is available on the requirements of nutrients by the very young pig. Neither is there much information available on the feeds to use and the best level to use them in these rations.

Thus, much remains to be learned concerning the composition of pre-starter and starter feeds. The rations recommended

TABLE XXXI Pig Pre-Starter and Starter Rations for Creep Feeding Suckling Pigs Recommended by Illinois Station (14)

Ingredients	Pre starter, lb	Starter, lb
Rolled oats or oat groats[a]	1100	350
Yellow corn (coarse grind)	—	1000
Molasses[b]	200	50
Sugar (cane or corn)	200	50
Soybean meal	400	450
Dried skim milk	100	100
Ground limestone	20	20
Dicalcium phosphate, defluorinated phosphate, steamed bone meal or equivalent	20	20
Trace mineralized salt or salt plus trace mineral mix	10	10
Total	2050	2050
Vitamins Added to Above Mix		
B vitamin premix[c]		
Riboflavin, grams	2	2
D calcium pantothenate, grams	4	4
Niacin, grams	4	4
Vitamin A, million units	5	5
Vitamin D_2 or D_3, million units	$^1/_2$	$^1/_2$
Vitamin B_{12}, mg	10	10
Antibiotics, grams	10	10

[a] If ration is to be pelleted, use rolled oats If ration is fed as a meal, the oat groats are slightly preferred

[b] Cane or corn sugar may be substituted for molasses at the rate of about 1 lb of sugar per 2 lb of molasses

[c] Commercial B vitamin premixes come in a number of combinations These are recommended proportions Those for riboflavin and calcium pantothenate should be followed closely, some variation is possible for niacin Choline is not included in this table, whereas it is in *Illinois Circular 719* Dr S W Terrill advised that it be left out in this table

by the Iowa and Illinois Stations and others which have been recommended by other experiment stations will undoubtedly be changed as more research information becomes available

TABLE XXXII. Pig Starter Recommended by Iowa Station (13)

Ingredients	Pounds
Sugar	150
Yellow corn (ground coarse)	300
Rolled oats	1000
60% fish meal or 50% meat and bone scraps good quality	50
Dried whey	50
Soybean oil meal	400
Vitamin A	6 million units
Vitamin D_2	1 million units
Vitamin B_{12}	40 mg.
Riboflavin	6 g.
Niacin	60 g.
Calcium pantothenate	6 g.
Choline Chloride	150 g.
Antibiotic(s)	40 g.
Ground limestone	15
Steamed bone meal (or equivalent)	30
Salt	10
Trace mineral mix	4
Total	2009 lb.

8.2f Grower Rations

After the pigs have a good start and weigh 25 or 30 pounds, they can be switched from the starter ration to a grower ration This, again, is not quite so highly fortified and consequently is less costly. At this stage, pigs start eating considerably more feed; thus, costs must be given more consideration. In grower rations, soybean oil meal may replace the dried skim milk and ground yellow corn may replace sugar and part of the rolled oats in the ration. Also, the amount of vitamin and antibiotic supplementation may be reduced.

8.2g Summary on Feeding Pigs to 8 Weeks of Age

Following are four plans which may be followed in raising pigs to 8 weeks of age:

Plan I. Wean pigs at 7 to 14 days of age, or when they weigh a minimum of 5 pounds body weight. Feed each pig 3 to 5 pounds of pre-starter feed for about 1 week. After the pigs are eating the pre-starter feed well, switch them to a starter feed until they weigh about 25 or 30 pounds and are looking thrifty (this should take 20 to 25 pounds of starter ration per pig). Then switch pigs to a grower ration for about 3 weeks, until they weigh about 50 pounds (this should take about 55 to 60 pounds of grower ration per pig.)

Plan II. Wean pigs at about 21 days of age. Feed pre-starter feed while pigs are with the sow and for a while thereafter until they have consumed about 3 to 5 pounds of it or are eating it well. Switch the pigs to a starter feed until they weigh 25 to 30 pounds and are looking thrifty. Then switch pigs to a grower ration until they weigh about 50 pounds.

Plan III. Wean pigs at 5 to 6 weeks of age. Feed pigs a prestarter and/or starter ration in a creep. If the pigs weigh 30 pounds or more and are thrifty at weaning, they can be placed on the grower ration until they weigh about 50 pounds. If the pigs weigh less than 30 pounds at weaning and are not too thrifty in appearance, continue feeding them the starter ration after weaning until they improve and appear thrifty. Then they can switch to the grower ration until they weigh about 50 pounds.

Plan IV. Wean pigs at 6 to 8 weeks of age. Feed pigs a starter feed in a creep. After weaning, feed the pigs a grower ration until they weigh about 50 pounds. Although most swine producers wean pigs earlier, there may be occasions when some will want to keep the pigs on the sow to 6 to 8 weeks of age.

The information in Table XXXIII shows the nutrients which the Iowa Station (5) recommends be included in pig pre-starter, starter, and grower rations. These figures can be used as a guide in compounding these rations. It must be stressed, however, that other investigators recommend slightly different levels, depending on the ration used and other variables. These figures

may be altered somewhat as more research is conducted on this problem and as more knowledge accumulates on the requirements of baby pigs for nutrients in these rations.

TABLE XXXIII. *Suggested Nutritional Allowances for Pig Feeds to 8 Weeks of Age by Iowa Station on March 1, 1957*[a] (5)

	Pig pre-starter[b]	Pig starter	Pig grower
Weight, beginning-end, lb.	8-10	10-25	25-50
Protein, %	25	18	16
Ca, %	0.8	0.8	0.8
P, %	0.7	0.7	0.7
Vitamin A, units/lb.	3000	3000	2000
Vitamin D_2, units/lb.	500	500	400
Riboflavin, mg /lb.	5	4	2.5
Niacin, mg./lb.	30	25	20
Pantothenic acid, mg./lb.	10	8	6
Choline, mg /lb.	500	450	400
Antibiotic, mg./lb.	50	50	25
Vitamin B_{12} μg /lb	20	20	10

[a] These nutritional allowances are suggested for optimum performance (not minimum requirements). They are based on the nutritional content of rations found to give satisfactory results in recent swine nutrition research. Other experiment stations, however, may recommend somewhat different levels of nutrients.

[b] Also needed are folic acid, 0.25 mg. per pound of ration.

8.3 FEEDING PIGS FROM 50 TO 200 POUNDS

Once the pig has reached about 50 pounds and is thrifty in appearance, it has about passed a nutritionally critical period. Until the pig weighs about 75 pounds, however, it is still not entirely past this period. But after the pigs weigh 75 pounds, they will do well on relatively simple rations. If 50-pound pigs are not too thrifty in appearance, it might be well to continue them on a grower ration until they weigh about 75 pounds. Then, the pig is ready for less highly fortified growing-fattening rations.

Since there is some difference of opinion as to fractionation of the growing-fattening period, two of the most commonly used are given and they are as follows:

I. Growing-Fattening Periods	II. Growing-Fattening Periods
50 to 100 pounds live weight	Weaning to 75 pounds live weight
100 to 150 pounds live weight	75 to 125 pounds live weight
150 to 200 pounds live weight	125 to 200 pounds live weight

In both cases, it has been shown that as the pig becomes heavier, the ration can be decreased in protein content as well as in certain other nutrients. Thus, the heavier the pig becomes, the less nutritionally fortified the ration needs to be

8.3a Dry Lot vs. Pasture

There is an increased interest in fattening hogs for market entirely in dry lot instead of using some pasture. This is particularly the case with farmers who wish to specialize in hogs and who are able to use modern buildings and labor-saving equipment efficiently the year around. In these instances, pastures will be used almost exclusively for the sow herd. Many swine producers, however, will continue to use a combination program of winter dry lot and summer pasture feeding. Especially will this be the case on diversified farms with legumes as part of the pasture program and rotation.

The trend, however, is for raising pigs more often in dry lot. This trend must be considered in formulating swine rations. Pasture feeding can cover up certain ration deficiencies which might show up in dry lot. Lush, green pasture supplies many vitamins, minerals, proteins, and unidentified factors. Thus, the feeder who is not using well-balanced rations will benefit from pasture feeding since it will cover up many of his mistakes. Rations fed in dry lot will need to be more nutritionally adequate than those fed on pasture.

In many areas, it will be more economical to fatten pigs in

dry lot and use the pasture for the sows. The limited length of the pasture season in the corn belt, the variability in quality and palatability of pasture, and the cost of pasture when compared to dry-lot feeding is responsible for the trend toward dry-lot feeding in many areas. Moreover, knowledge of nutrition has increased to the point where rations can be properly balanced and fortified so that pigs will do as well in dry lot as on pasture.

One must keep in mind, however, that high-quality pasture can, on the average, replace 10 to 15 per cent of the concentrates and 25 to 50 per cent of the protein supplement. Thus, the economy of the situation must be carefully considered when one is deciding on whether to fatten pigs in dry lot or on pasture.

8.3b Complete Rations vs. Corn and Supplement Free-Choice

There is some difference of opinion as to which is the best method to use. Self-feeding grain and supplement free-choice offers the most simple program. But the efficiency of this method may vary, depending on the palatability of the supplement and that of the grain and pasture. Protein supplements need to be compounded so that they will not be too palatable, thus encouraging overconsumption by the pigs. The addition of alfalfa meal, minerals, and other feeds will lessen the palatability of the protein supplement mixture (see section 7.4a). Palatability of the corn and pasture will also vary, depending on variety, soil fertility, maturity, and many other factors.

Thus, the feed manufacturer and swine producer will need to compound supplements which will do an efficient job with the pastures and grains available in the area. The swine producer will need to keep accurate records to determine which method of feeding will be the most economical under his conditions. He must balance the cost of grinding and mixing against the inefficiency of overeating or undereating which may occur if the protein supplement is self-fed. Moreover, he has the advantage for self-feeding of having the grain already on his farm. This advantage can be overcome, however, if arrangements can be made for him to supply his own grain to be mixed or deliver

grain to be credited to future complete mixed rations. If these arrangements can be made, many swine producers will favor custom-mixing or bulk deliveries of complete mixed rations.

Some experiments show no difference between complete rations and free-choice rations, whereas others do. The differences obtained are due to the conditions under which the experiments were conducted. Thus, conditions on the farm will determine which system of feeding will be the most economical. Under some conditions, complete rations will be best, whereas free-choice feeding of grain and protein supplements will be superior in others. In most cases, the farmer will use some complete rations and will also free-choice feed others, depending on the stage of the life cycle of the pig and how its overall requirements can best be met. Many feeders are using complete ground and mixed rations for young pigs—when nutritional needs are most critical. There is also an increasing trend toward the use of mixed rations for older pigs. This is done as a means of controlling the nutrient and antibiotic intake rather than trusting the pigs to consume the correct amount when they are self-fed corn and supplement free-choice.

8.3c Suggested Nutrient Content of Rations

There is considerable variation in the nutrient content of various rations recommended by different investigators. The nutrients recommended by the Iowa and Illinois Stations are given in Tables XXXIV, XXXV, and XXXVI. These can be used as a guide by those interested in compounding rations. Table XXXIV gives three recommended protein supplements for growing-fattening pigs in dry lot and on pasture. These supplements can be used as guides as to what might be included in them. Moreover, the table gives information on the vitamin, antibiotic, and mineral supplements which the Illinois Station recommends for such supplements.

Table XXXV gives information on the amount of supplement to feed with corn for pigs in dry lot or on pasture. This can also be used as a guide for those who wish to compound com-

TABLE XXXIV. Suggested Rations and Supplementation by Illinois Station[a] (14)

Feeds	Supplement[f] (pounds, unless otherwise indicated)		
	Pig	Hog	Pasture
Approximate protein content, per cent	35	38	40
Soybean meal	800	800	1100
Cottonseed meal, linseed meal, or peanut meal[b]	200	200	300
Tankage, meat scrap, meat and bone scrap, or fish meal	300	400	400
Dried whey, dried skim milk, fish solubles, or dried corn distillers' solubles	200	100	—
Dehydrated alfalfa meal	300	300	—
Ground limestone	80	80	120
Steamed bone meal, dicalcium phosphate, or equivalent	80	80	120
Trace mineralized salt or salt plus a trace mineral	40	40	60
Total	2000	2000	2100
Premixes or special supplements[c]			
B-vitamin premix:[d]			
Riboflavin, grams	5	3.75	2.5
d-Calcium pantothenate, grams	10	7 5	5.0
Niacin, grams	10	7 5	5.0
Vitamin B_{12}, mg.	30	40	40
Vitamin D_2 or D_3, million units[e]	1	1	—
Antibiotic, grams	50	50	70

[a] These are only examples; other combinations may be equally good or perhaps better.

[b] Soybean meal may replace cottonseed, linseed, or peanut meal; or vice versa, up to 25% of the total.

[c] B-vitamin premixes, vitamin B_{12} supplements, antibiotic supplements, and vitamin A or D supplements, or both may be used to furnish specified amounts

[d] Follow recommendations for riboflavin and calcium pantothenate closely; some variation is possible for niacin. If the pasture is excellent, the premix furnishing these three vitamins may be eliminated from the pasture supplement. Choline is not included in this table, although it is included in *Illinois Circular* 719, from which this table was taken. Dr. S. W. Terrill, University of Illinois, advised that choline be left out of this table.

[e] When hogs are exposed to sunlight daily, the vitamin D additions are not necessary.

[f] Pig supplement is to be fed in dry lot with home-grown grains from weaning until the pig weighs about 75 lb. The hog supplement is to be fed in dry lot from 75 lb. to market weight. The pasture supplement is to be fed to hogs of all ages that are on good pasture.

plete rations, using grain mixed with the protein supplement This table also can be used to excellent advantage by the feeder as a good guide to whether his pigs are consuming too much or not enough supplement It shows that the amount of protein needed on good quality pasture is 2 per cent less than in dry lot It also brings out the fact that poor-quality pasture is not of much value and protein requirements there are about the same as in dry lot This means that poor pastures are actually not much more than exercise yards for the pigs Many swine producers run into difficulties because they assume their poor-quality pastures are good ones and thus their pigs do poorly

TABLE XXXV Amount of Crude Protein and Supplement Recommended in Hog Rations by Illinois Station (14)

	Average total daily feed (pounds)	Per cent crude protein	Ratio of supplement to corn[a]	Pounds of supplement per hog per day[b]
	In Dry Lot or on Poor Pasture			
Weaning to 75 lb	3 2	16	1 3	0 8
75 to 125 lb	5 3	14	1 4	1 1
125 lb to market	7 5	12	1 7	0 9
	On Good Pasture			
Weaning to 75 lb	3 2	14	1 5	0 5
75 to 125 lb	5 3	12	1 8	0 6
125 lb to market	7 5	10	1 15	0 5

[a] Assumes that yellow corn (8 0–8 5% crude protein) is mixed or fed with supplements containing about the same amount of crude protein as shown in Table X

[b] Figures in this column may be used to check whether pigs fed free choice are getting too much or not enough supplement They may also be used as a guide in hand feeding

The information in Table XXXVI shows the suggested nutritional allowances for growing-fattening pigs by the Iowa Station These recommendations vary in some respects with those of other stations They are, however, representative of the thinking of many investigators They are not much differ-

ent from the nutrient requirements recommended by the National Research Council in Table I. The protein levels are lower than those recommended by the National Research Council. All the other nutrients, however, are either higher than the National Research Council recommendations or about the same.

Thus, the Iowa Station recommendations can be used as one guide concerning the amount of certain nutrients needed in rations for growing-fattening pigs. It must be kept in mind, however, that other stations may give slightly different recommendations. Thus, feeders and feed manufacturers should be aware of the recommendations made by the various experiment stations in their areas. These recommendations may vary to take care of different feeds and feeding programs suited to that area.

TABLE XXXVI. *Suggested Nutritional Allowances for Growing-Fattening Pigs by Iowa Station on March 1, 1957*[a] (5)

Weight, lb.	50–100	100–150	150–200
Protein, %	14–16	12–14	10–12
Ca, %	0 8	0.7	0.7
P, %	0 6	0.5	0.5
Vitamin A[b] (carotene), units/lb	500 (1250)	500 (1250)	500 (1250)
D_2, units/lb.	300	300	200
Riboflavin, mg /lb.	1.5	1.5	1.4
Pantothenic acid, mg /lb.	5	5	4
Niacin, mg /lb.	15	15	10
Antibiotic, mg./lb.	5	5	4
B_{12}, micrograms/lb.	5	5	4

[a] These nutritional allowances are suggested for optimum performance (not minimum requirements). They are based on the nutritional content of rations found to give satisfactory results in recent swine nutrition research. Other experiment stations, however, may recommend somewhat different levels of nutrients.

[b] About 2.5 times as many I.U. of provitamin A (carotene) as true vitamin A are needed. To convert carotene to I.U. units of vitamin A, multiply the number of milligrams of carotene by 1000 and divide by 0.6, or multiply the milligram of carotene by 1666.6.

8.3d Feeding Herd Replacement Animals during Growth

Some unknown factor (or factors), present in high-quality alfalfa meal, is definitely needed for reproduction and lactation. This factor (or factors) is stored for a long period of time. Such storage is so important that the ration a pig receives during

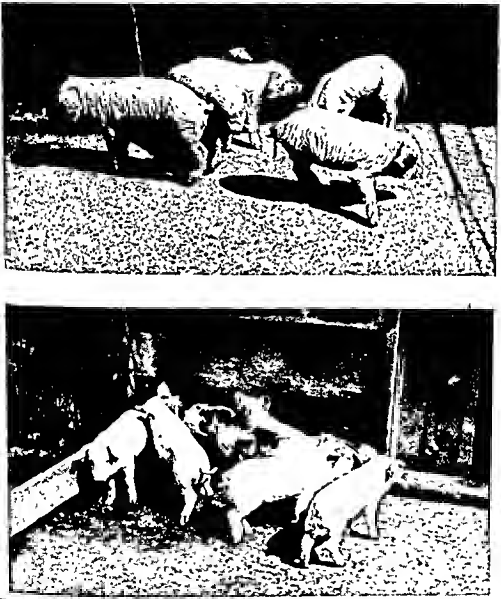

Fig. 43. Note the difference in thriftiness between pigs above from sows fed 5 per cent alfalfa meal as compared to those below from sows fed 15 per cent alfalfa meal. Higher levels of high-quality alfalfa meal are valuable for sows fed in dry lot. (Courtesy G. Bohstedt, T. J. Cunha, O. B. Ross, and P. H. Phillips, Wisconsin Agricultural Experiment Station.)

growth will definitely influence the ability of the animal to conceive, reproduce, and lactate many months later (6–8). Thus, prospective herd replacement gilts should be fed differently and much better than pigs being fattened out for market.

A farmer who feeds his herd replacement gilts and market hogs together may run into difficulties in his breeding program. In too many cases, all the pigs are fed together. Then, when they all reach market weight, the herd replacement gilts are sorted out. That procedure is all right if excellent rations are fed during growth. Many farmers, however, do not feed highly nutritious rations to pigs which are going to be sold as market hogs. As a result, when they sort out the replacement animals they may have some unsuitable for breeding purposes.

The best rations—adequate nutritionally—should be fed to prospective breeding animals. In other words, one should sort out his prospective herd replacement gilts soon after weaning and feed them excellent rations all during their growing period. This will pay big dividends later, because the gilts will settle quickly and will farrow large litters and wean a high percentage of their pigs.

If gilts are farrowing small litters and losing most of their pigs before weaning time and the trouble seems to be nutritional, the ration fed during gestation and lactation should not be blamed entirely; the ration fed during the growth period may have been inadequate and thus responsible for the poor results. Breeding animals should always be fed good, well-balanced rations before and after they are bred or have farrowed a litter. If poor rations are fed too long during growth, gilts may become so depleted that it is too late to build them up later on with a good ration so that they are able to raise large, healthy litters of pigs.

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growth will definitely influence the ability of the animal to conceive, reproduce, and lactate many months later (6–8). Thus, prospective herd replacement gilts should be fed differently and much better than pigs being fattened out for market.

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CHAPTER IX

Feeding the Breeding Herd

9 0 INTRODUCTION

To make profit, a swine producer needs to develop a feeding and management program which results in large, heavy litters at birth and at weaning time At present, it is estimated that between 30 and 40 per cent of all pigs farrowed die before they reach market Nutritional deficiencies account for a good part of these losses (section 1 2) Thus, proper feeding of the breeding herd can eliminate, to a large extent, the handicap of these enormous "small pig losses" which the farmer has to contend with

An Illinois study showed that maintaining the breeding herd accounts for about 30 per cent of the total cost of hog production The other 70 per cent of the cost is involved in growing pigs from weaning to market Feed makes up about 80 per cent of the cost of maintaining the breeding herd Thus, an economical feeding program for the breeding herd is essential

Besides the cost involved, the feeding program determines the number, weight, and strength of the pigs in each litter Their survival rate and weaning weights are also dependent on ration adequacy A poor feeding program will raise havoc with the first phase of raising and producing a market hog

9 1 FEEDING PROSPECTIVE BREEDING ANIMALS

Prospective breeding gilts need to be fed excellent rations during the time they are growing The ration fed during growth, from weaning to breeding age, has been shown to affect the results obtained many months later during conception, gestation, and lactation (10,11,22,29) This means that a producer should

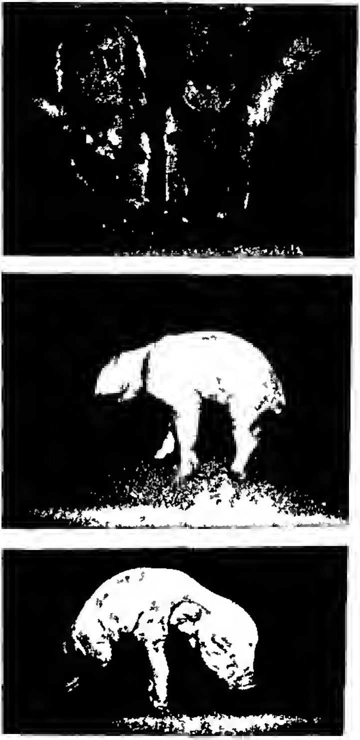

Fig 44 Note leg abnormalities obtained in pigs from sows fed corn soybean rations with 5 per cent of alfalfa meal in dry lot during their growing period, as well as during gestation No such abnormalities were obtained with sows fed 15 per cent high-quality alfalfa meal during same period (Courtesy P H Phillips, T J Cunha, O B Ross, and G Bohstedt, Wisconsin Agricultural Experiment Station)

sort out his prospective herd replacement gilts soon after weaning and feed them a well-balanced ration during growth. This will result in the gilts' developing the normal reproductive tract which is necessary for production of large, thrifty litters (sections 8.1 and 8.3d).

Alfalfa meal contains some unidentified factor or factors which are of considerable value for pigs during growth and which influence their ability to conceive, reproduce, and lactate many months later (10,11,29). A level of 5 per cent alfalfa is not high enough—10 or 15 per cent alfalfa is needed to supply this factor or factors with corn-soybean rations. High-quality pasture would most likely supply this same factor or factors.

This means that prospective replacement animals should be fed on good pasture or have higher levels of alfalfa meal in the ration during growth. Experimental information is not available on the effect of growth ration on their breeding ability, but it would probably be a good idea to treat prospective herd boars just like the gilts. Therefore, the first step in feeding the breeding herd is to grow out replacement animals properly so they will have normal reproductive organs when they enter the breeding herd. This will eliminate sterile or poor-breeding boars and gilts. A swine enterprise has two strikes against it if it starts out with unproductive gilts or boars.

9.2 FEEDING DURING THE BREEDING SEASON

An excellent ration, adequate in energy, vitamins, minerals protein, and fat, should be fed during the breeding season This ration can be the same as the one used during the gestation period. The practice of "flushing" or having the sows gaining in weight just before breeding is practiced by some breeders. The beneficial effect of flushing, beginning 21 days before breeding, has been substantiated by experimental studies at the Wisconsin Station. Flushing increases the number of eggs produced by the sow at breeding time, which in turn increases litter size.

The rate of gain to be desired would depend on the condition and size of the sow. If they are in thrifty condition, neither

gestation period; it will also depend on what the gilts were fed during their growing period (10,11,29). Thus, the developing fetus makes most of its growth during the last third of gestation; but it has its fate determined previous to and during the whole gestation period.

TABLE XXXVII. Computed Weight and Composition of a Litter of Eight Pigs during Gestation (23)[a]

Week of gestation	Total fresh weight, grams[b]	Crude protein, grams	Ash, grams	Calcium, grams	Phosphorus, grams	Iron, mg[b]
1	99	1 5	0 06	0 0002	0 002	0 82
2	366	8 5	0 6	0 005	0 028	4 2
3	787	23	2	0 036	0 12	11
4	1,354	47	5	0 14	0 36	22
5	2,062	83	10	0 40	0 82	37
6	2,909	130	18	0 96	1 61	57
7	3,891	191	30	2 0	2 8	82
8	5,005	265	45	3 8	4 7	113
9	6,251	356	66	6 6	7 2	149
10	7,625	462	92	10 9	10 6	191
11	9,127	585	125	17 1	15 1	239
12	10,755	726	165	26	21	294
13	12,507	886	213	38	28	355
14	14,385	1,065	269	54	37	423
15	16,384	1,263	335	74	47	499
16	18,504	1,483	411	101	60	581

[a] These data were obtained from Poland China gilts bred to the boar of the same breed They were all fed the same ration in amounts to produce an average daily gain of 1 to 1.25 lb

[b] One pound contains 452 grams or 452,000 mg.

9.3b Gain during Gestation

A gilt should gain enough to compensate for the weight of the litter and afterbirth, as well as for a normal increase for her growing body. This means that gilts should gain from 100 to 125 pounds during gestation. Sows need to gain less, since they are not growing and need only to maintain their body weight.

too fat nor too thin, they should be gaining in the neighborhood of about a pound per day prior to breeding. Sows and boars should be in thrifty condition during the breeding season. It is usually necessary to decrease gradually, before the breeding season, the condition of sows and boars which are in high condition so that they will breed well. On the other hand, animals which are too thin should increase in flesh to get into thrifty condition by breeding time. Sows which respond to "flushing" are those which are in thin condition to begin with. The extra feeding of thin sows and boars evidently stimulates the endocrine and reproductive system to greater activity.

9.3 FEEDING DURING GESTATION

An excellent, well-balanced ration is very important during gestation. Gilts will have greater requirements than mature sows because their ration will have to take care of their growth as well as that of the developing fetus. Thus, gilts need more feed per 100 pounds of body weight.

9.3a Amount to Feed

It is recommended (see Table II) that a 300-pound gilt be fed 6 pounds of feed daily, or at the rate of 2 per cent of their body weight. A 500-pound mature sow should be fed about 7.5 pounds of feed daily, which is 1.5 per cent of their body weight. Feed young and mature boars at the same rates as gilts and sows (see Table II). These levels of feeding will vary somewhat depending on the ration used and on the condition of the animals. Decrease the rate of feeding if the animals start to get too fat and increase it if they are still too thin. With bulky rations, increase the level of feeding.

The developing young make over half of their growth during the last one-third of the gestation period (Fig. 3 and Table XXXVII). However, do not wait until then to feed a well-balanced ration. The thriftiness of the litter at birth and their survival rate will depend on the ration fed during the whole

9.3c Value of Forages and Alfalfa

High-quality pasture has some factor or factors needed for satisfactory results during reproduction Rations which are adequate for sows on pasture have been found to be inadequate when fed in dry lot (10,11,14,18,20,21,22,25) Alfalfa meal has been shown to do as well as rye pasture in supplementing a ration for brood sows (3) Excellent, high-quality alfalfa meal has been shown to do a good job as a pasture substitute in dry-lot rations A level of 5 per cent alfalfa is not enough Higher levels of 10 to 15 per cent alfalfa will usually give better results, especially if the ration is not properly fortified with B-complex vitamins

9 3d Rations To Use

There is considerable variation in the rations recommended for sows during gestation as well as during lactation Tables XXXIX, XXXX, and XXXXI give recommended rations

TABLE XXXIX Sow Rations Recommended by Iowa Station (5)

Sow Supplement	
Ingredients	*Amounts*
50% meat and bone scraps	400
44% soybean oil meal	700
Standard wheat middlings	200
Dehydrated alfalfa meal	500
Steamed bonemeal	160
Iodized salt	40
Trace mineral premix	15
Vitamin antibiotic premix	
Vitamin D_2	5 million I U
Riboflavin	2 grams
Calcium Pantothenate	2 grams
Niacin	90 grams
Choline chloride	200 grams
Vitamin B_{12}	70 mg
Antibiotic(s)	70 grams
	2015

Continued

Sows should gain 75 to 100 pounds during gestation. This gain would allow the sow to take care of weight losses during parturition and lactation and still weigh approximately the same when she weans her pigs as when she was bred.

These weight gains for gilts and sows will vary, depending on their original condition. The kind of ration used may also modify the weight gains needed. Swine producers can use these recommended gains for gilts and sows as a guide. See Table XXXVIII for information on the weight losses which occurred with gilts and sows during parturition and the suckling period in a 15-year period at Purdue University.

TABLE XXXVIII. *Weights, Gains, and Weight Losses in Gilts and Mature Sows from Breeding to Weaning (28)*

	No of Sows, 445	No of Gilts, 248
Average weight when bred	404.05	260.41
Average weight before farrowing	492.96	354.63
Average gain during gestation	88.91	94.22
Average gestation days	113.36	113.55
Average daily gain during gestation	0.78	0.83
Average weight after farrowing	455.20	327.14
Average weight loss at farrowing	37.76	27.49
Average weight at weaning	423.39	299.00
Average loss during suckling[a]	−31.82	−28.15
Total loss at farrowing and during suckling	−69.58	−55.64

[a] Occasionally there was a year when the sows or gilts actually gained during the suckling period. These data were obtained over a 15-year period.

During gestation, the gilt or sow needs to build up body reserves to be used during lactation. The weight loss during lactation will vary with the litter size, the condition of the animal, the adequacy of the ration fed, and the milking ability of the sow. Thus, weight losses during lactation will vary somewhat from the figures shown in Table XXXVIII; however, the figures given there can be used as a guide.

is due to the different feeds and their levels used in the rations Part of this difference is also due to the fact that more experimental information is still needed on levels of various vitamins, minerals, protein, and other nutrients needed in sow rations As time progresses, more exact information will become available These rations, however, are all good ones and can be used as guides in making up rations

Other experiment stations have recommended excellent rations, but space limitations prevent their inclusion here It is suggested, however, that those making up rations check with their state experiment stations for their recommendations for local conditions

Tahle XXXXII gives the nutrient levels suggested for pregnant and lactating sows by the Iowa Station (4)

The level of protein recommended is in line with National Research Council (NRC) recommendations (see Table I) The calcium, phosphorus, vitamins A and D, and niacin recom

TABLE XXXX Sow Rations Recommended by Illinois Station[a] (27)

Sow Supplement	
Soybean oil meal	800
Tankage meat scrap meat and bone scrap or fish meal	300
Cottonseed meal linseed meal or peanut meal[b]	100
Dried whey dried skim milk *fish solubles* or dried corn distillers solubles	200
Dehydrated alfalfa meal	400
Ground limestone	100
Steamed bone meal dicalcium phosphate or equivalent	80
Trace mineralized salt or salt plus a trace mineral mix	40
Premixes or special supplements[c]	
B-Vitamin premix[d]	
Riboflavin grams	5
d Calcium pantothenate, grams	10
Vitamin B_{12}, mg	25
Vitamin D_2 or D_3 million units[e]	1
Vitamin A, million units	10

Continued

TABLE XXXIX (*Continued*)

Complete Balanced Rations

For Sows During Gestation

Ration 1. Complete ration for self-feeding		
Ground corn	600 lb.	If sows get too fat, lower corn and increase alfalfa meal. If sows are too thin, increase corn and decrease alfalfa meal.
Ground oats	600 lb.	
Alfalfa meal	500 lb.	
Sow supplement	300 lb.	
	2000 lb.	
Ration 2. Self-fed ration with corn hand-fed		
Ground oats	800 lb.	Let sows clean up corn in fields or hand-feed corn according to conditions. *Do not get sows fat.*
Alfalfa meal	800 lb.	
Sow supplement	400 lb.	
	2000 lb.	

Ration 3. Hand-feed grain and sow supplement: hand-feed $^3/_4$ to 1 lb. of sow supplement per head daily. Gilts need the most. Hand-feed corn and oats according to condition. Alfalfa hay may be self-fed free-choice in addition.

Before and After Farrowing Ration

Ration 1 above is a good ration to feed 3 to 5 days before and 3 days after farrowing.

For Sows During Lactation

Sows and litters may be self-fed successfully shortly after farrowing. Heavy milking sows may have to be hand-fed the first week. *Be sure to supply plenty of water!*

Ration 4. Self-fed free-choice shelled corn and sow supplement.

Ration 5. Complete ration for self-feeding sows and litters.

Ground corn	1200 lb.
Ground oats	400 lb.
Sow supplement	400 lb.
	2000 lb.

from the Iowa, Illinois, and Michigan experiment stations. A close examination of these rations will show variation in feeds used and levels of supplements recommended.

In part, the difference in amount of supplements recommended

TABLE XXXXI. Sow Rations Recommended by Michigan Station (17)

Sow Supplement[a]

Soybean meal	580
Tankage or meat scraps	150
Fish meal	50
Alfalfa meal	150
Dicalcium phosphate or bone meal	40
Trace mineralized salt	30
Irradiated yeast, million units	1
Antibiotics, grams	30
B_{12}, mg.	25
B vitamins	[b]

Suggested Gestation Rations

	Gilts		Sows	
	Hand-fed	Self-fed	Hand-fed	Self-fed
Corn (wheat, barley)	450	300	450	230
Oats (middlings, bran)	250	300	300	350
Alfalfa meal (hay)	150	300	150	350
Sow supplement above[a]	150	100	100	70
Estimated protein (per cent)	15.1	15.1	13 9	14.8

Suggested Lactation Rations

Ration	No. 1	No. 2
Corn (barley, wheat)	600	700
Oats	200	...
Wheat standard middlings	—	150
Sow supplement above[a]	200	150
Estimated protein (per cent)	15.5	15.0

[a] Contains 38–40% protein.
[b] Use commercial vitamin concentrate supplying riboflavin, pantothenic acid, and niacin according to manufacturer's instructions.

level which appeared adequate to support normal reproduction in sows in an Illinois study (see section 4.14d).

It must be pointed out, however, that the studies with riboflavin and pantothenic acid at levels higher than those recom-

TABLE XXXX (*Continued*)

Recommended Amount of Crude Protein and Supplement to Feed

		Avg. total daily feed	Per cent crude protein	Ratio of supplement to corn[f]	Pounds of supplement per day[g]
In dry lot or poor pasture					
Gestation	Gilts	5.0	15	1:2.9	1.3
	Sows	5.0	14	1:3.6	1.1
Lactation	Young females	11.0	15	1:2.9	2.8
	Mature sows	12.5	14	1:3.6	2.7
On Good Pasture					
Gestation	Gilts	4.0	13	1:6	0.6
	Sows	4.0	12	1:8	0.5
Lactation	Young females	11.0	13	1:6	1.6
	Mature sows	12.5	12	1:8	1.4

[a] These are only examples; other combinations may be equally good or perhaps better.

[b] Soybean meal may replace cottonseed, linseed, or peanut meal; or vice versa up to 25% of the total.

[c] B vitamin premixes, vitamin B_{12} supplements, antibiotic supplements, and vitamin A or D supplements, or both may be used to furnish specified amounts

[d] Follow recommendations for riboflavin and calcium pantothenate closely. If the pasture is excellent, the premix furnishing these two vitamins may be eliminated from the pasture supplement.

[e] When hogs are exposed to direct sunlight daily, the vitamin D additions are not necessary.

[f] Assumes that yellow corn (8.0–9.0% crude protein) is mixed or fed with supplements containing about the same amount of protein (34%) as the one shown in this table.

[g] Figures in this column may be used to check whether sows or gilts are getting too much or not enough supplement. They may also be used as a guide in handfeeding.

mendations are somewhat higher than NRC recommendations (see Table I). The riboflavin level is higher than that recommended by NRC (see Table I) but is lower than levels used successfully by the U.S.D.A. and Illinois in experimental studies (see section 4.12d). The pantothenic acid level is higher than the level recommended by NRC, but is lower than a 5.7 mg.

per litter Swine producers should set as a goal the weaning of 8 to 10 or more pigs per litter

TABLE XXXXIII Feed Costs are Lower with Bigger Litters (17)

Number of pigs weaned	Pounds of feed per pig		
	At weaning	From weaning to 225 lb	Total feed per pig at 225 lb
	lb	lb	lb
2	722	653	1375
4	368 5	653	1021 5
6	250 6	653	903 6
8	191 7	653	844 7
10	156 4	653	809 4

9 3c The Value of Antibiotics

As previously discussed (see section 6 0b) in Chapter VI, the evidence on the value of antibiotics for sows during gestation and lactation is still inconclusive However, information obtained to date indicates no harmful effect and possibly a beneficial effect from including aureomycin in the ration for sows Table XXXXIV shows information obtained at the Georgia Station (26) which indicates less pig mortality with the sows fed aureomycin

A U S D A study (12,13) confirms the Georgia work, since these investigators also found that feeding aureomycin to the sow increased survival of the young in the first few days of life Purdue data (1) showed that feeding aureomycin to brood sows significantly increased birthweight (0 2 to 0 3 pound heavier pig) and usually resulted in stronger pigs All this information would indicate that it would be good insurance to include an antibiotic in sow rations

It is apparent that antibiotic feeding to sows is not harmful and may be of value in certain cases The beneficial effect may occur when stress factors such as disease level, quality of ration, and sanitary conditions are operating Thus, it is quite possible that antibiotics may be beneficial to the sow, under average farm

TABLE XXXXII. Nutritional Allowances Recommended for Gestation and Lactation by Iowa Station[a] (4)

Protein, %	14–15
Calcium, %	0.90
Phosphorus, %	0.60
Vitamin A[b] (carotene), units/lb.	2600 (6500)
Vitamin D_2, units/lb.	400
Riboflavin, mg./lb.	1.5
Niacin, mg./lb.	15
Pantothenic acid, mg./lb.	5
Antibiotic(s),[c] mg./lb.	5
Vitamin B_{12}, μg./lb.	5

[a] The nutritional requirements above are suggested for optimum performance (not minimum requirements). They are based on the nutritional content of rations found to give satisfactory results in recent swine nutrition research.

[b] About 2.5 times as many I.U. of provitamin A (carotene) as true vitamin A are needed. To convert carotene to I.U. of vitamin A, multiply the number of milligrams of carotene by 1000 and divide by 0.6, or multiply the milligrams of carotene by 1666.6.

[c] Antibiotics are not considered nutrients. Amount to use depends on the antibiotic, disease level, level of interrelated nutrients, and/or stage of the life cycle (see Table XVIII).

mended by the Iowa Station were not established as optimum levels. It is possible that levels somewhat lower than those used would also have been adequate. Thus, it appears that the levels of nutrients recommended for sows by the Iowa Station in Table XXXXII are adequate with the possibility that the riboflavin and pantothenic acid levels might be increased a little.

There is very little information on the level of antibiotics and vitamin B_{12} to feed to sows. Thus, the Iowa Station recommendation is a good guide to use until more information becomes available.

It is very important that excellent rations be fed to sows, since large litters cannot be produced without adequate nutrition. Table XXXXIII illustrates this point by showing that feed costs are greatly decreased as more pigs are saved and weaned

Some stations are experimenting with levels of 10 to 100 grams of antibiotic per ton of feed for sows 3 to 5 days before and after farrowing The thinking is that a high level of antibiotic at this time will prevent infections and complications which sometimes arise during the farrowing period

9 3f Self-Feeding vs Hand-Feeding

More farmers are interested in self-feeding sows because it saves time and labor It also gives the timid sow a chance to get her share of the ration For example, Minnesota workers (15) have observed that pigs have a definite social order among themselves This behavior pattern is emphasized especially when the feed supply is restricted and the pigs are fed in fairly large groups The more aggressive pigs get more than their share of the feed, and the timid, less aggressive ones get much less than their share

This behavior pattern is not a problem when hogs are self-fed in groups with plenty of feeder space, since even the greedy ones do not eat all the time The Minnesota group successfully self-fed a ration containing 15 per cent ground corn cobs to begin with and gradually increased this to 35 per cent of corn cobs

Hand-feeding has been practiced almost exclusively in the past It allowed control in rate of gain and in the proper amount of supplement for the sow or gilt More recently, however, we have found that the same thing can be accomplished by self feeding a ration made bulky by the addition of large amounts of high fiber feeds such as oats, alfalfa, wheat bran, and corn and cob meal A well-balanced supplement is included in these bulky rations to make them adequate in protein, minerals, vitamins, and other nutrients Tables XXXIX and XXXXI give suggested rations by the Iowa and Michigan stations for self-feeding gilts and sows Table XXXXV gives rations for self-feeding pregnant sows and gilts by the Illinois Station (27)

Care must be taken to follow closely the condition of sows and gilts self fed their rations If they start to become too fat, the amount of bulk in the ration should be increased a little Like-

TABLE XXXXIV. Effect of Feeding Aureomycin to Sows at Georgia Station(26)

	Without aureomycin	With aureomycin[a]
Sows bred	37	38
Litters farrowed	35	35
Avg. no. pigs farrowed alive	8.42	9.28
Avg. no. pigs farrowed dead	1.52	0.86
Avg. birthweight, lb.	2.73	2.79
Avg. 21-day weight, lb.	10.75	10.67
Avg. no. pigs weaned per litter	5.70	7.29
Avg. weaning weight, lb.	34.6	32.9

[a] *Includes data on all first- and second-generation animals.*

conditions, where sanitation is sometimes poor and rations are not always well balanced.

Table XVIII gives a summary of recommended levels of antibiotics to use for sows during gestation and lactation. The average figure was 6.1 mg. of antibiotic per pound of feed or 12.2 grams per ton of feed. The Purdue Station (1), however, found that higher levels of antibiotics are required in the gestation ration of sows (30 grams per ton) as compared to the amount needed for growing-fattening pigs (10 grams per ton), because the feed intake during gestation is limited to approximately one-third to one-half of a full feed. Therefore, the intake of the antibiotic per unit of body weight is about the same for breeding and for fattening hogs. For this reason, it might be well to consider using a higher level of antibiotic than 12 grams per ton—probably near the 30-gram-per-ton level—during gestation.

The U.S.D.A. (12) fed a high level of 100 and 200 grams of aureomycin per ton of feed during growth and reproduction and found it had no harmful effect. If anything, the higher antibiotic levels seemed to have a tendency to save more pigs up to weaning time and to result in heavier weaning weights. Thus, a 30-gram-per-ton level during gestation would not seem to be excessive or apt to cause harmful effects.

large volume. Cobs are bulky and fibrous and thus would be a bulky feed They would result in a cheaper ration for self-feeding pregnant sows The researchers obtained excellent results with a gestation ration containing 35 per cent ground corncobs, 43 5 per cent ground corn, 5 per cent blackstrap molasses, 5 per cent soybean oil meal, 5 per cent meat and bone scraps, and 5 per cent alfalfa meal, plus minerals The cobs were ground through a $^1/_2$-inch hammermill screen initially But sorting of the large particles by the pigs resulted in wastage and in the consumption of an insufficient quantity of the cob Grinding the cobs through a $^1/_4$-inch hammermill screen, however, greatly reduced the amount of wastage and produced favorable results Adding 5 per cent of blackstrap molasses in the ration increased consumption of the ground cob portion of the ration and reduced wastage

9.3g The Feeding Value of Silage

Many swine producers have been feeding their sows more energy feed than they actually need during pregestation and gestation As a result the sows get too fat A fat sow usually kills more pigs by laying or stepping on them As a result, many swine producers have been feeding high roughage and silage rations as a means of decreasing the amount of energy fed their sows This keeps them from getting too fat

Florida data (9) showed that limited-fed sows usually farrowed in a few hours, whereas full-fed sows, which were overfat, took approximately 12 or more hours to farrow

Information available on the feeding value of silage for sows is still limited A limited amount of work has been conducted at the Indiana, Iowa, Illinois, and other experiment stations Thus, this discussion on silage feeding will be based on limited information

Following are some of the advantages and problems involved in feeding silage to sows

Advantages to feeding silage to sows

1. Feeding silage may reduce the cost of pigs at farrowing.

TABLE XXXXV. Bulky Rations Recommended by Illinois Station for Self-Feeding Pregnant Sows and Gilts[a] (27).

Ingredient	Bred sows		Bred gilts		Just before and after farrowing
Ground yellow corn	600	—	600	—	600
Ground oats	600	—	500	—	600
Ground alfalfa hay	650	700	600	600	—
Ground ear corn	—	1000	—	1000	—
Wheat bran	—	—	—	—	600
Sow supplement[b]	150	300	300	400	200
Total	2000	2000	2000	2000	2000
Crude protein, %	14	14	15	15	15

[a] *These are only examples; other combinations may be equally good or even* better. If sows get too fat, decrease corn and increase alfalfa hay, if too thin, increase corn.

[b] On good succulent pasture, substitute pasture supplement for sow supplement and use half the indicated amounts of supplement. The sow supplement is shown in Table XXXX. The pasture supplement is shown in Table XXXIV.

wise, if they do not look thrifty enough, the bulk in the ration should be reduced. Thus, rations recommended in this chapter might need to be altered somewhat depending on the response obtained in feeding them. The hazard in self-feeding rations to breeding animals is that they may overeat and thus become too fat.

The Minnesota (16,24) and Purdue (8) Stations, as well as others, have successfully self-fed rations to sows and gilts. Both methods of feeding have resulted in satisfactory and about equal litters. So, if the ration is bulky enough so that they do not become too fat, rations can be self-fed successfully to gilts and sows.

Recently, the Purdue Station (8) has tried ground corncobs as a means of adding bulk to a ration for self-feeding sows. Ear corn contains about 20 per cent cobs by weight, and extra cobs are readily available and cheap in areas where corn is grown in

Grass Silage

	Methods Used to Make Grass Silage			
	Wilted silage (Preserved with molasses or corn)		Nonwilted silage (Preserved with molasses or corn)	
	Grain and supplement per head per day (pounds)			
Grain (shelled corn equivalent)	2 (Ranging from 1 to 3)		2.5 (Ranging from 2 to 3)	
35% balanced supplement	0.5 (Ranging from 0.5 to 1)		0.5 (Ranging from 0.5 to 1)	
	Per cent protein in total rations when feeding 0.5 pound 35 per cent balanced supplement with variable amounts of grain			
	(Pounds shelled corn)		(Pounds shelled corn)	
	1.5	2.0	2.0	3.0
	(Per cent protein)		(Per cent protein)	
Sows	17.0	16.2	15.3	14.0
Gilts	16.6	15.7	15.4	14.0

TABLE XXXXVI. Level of Supplementation of Silage for Sows During Pregestation and Gestation Recommended by Iowa Station (5)

Corn Silage

	Silage (Full-Fed) Made from Corn Yielding							
	Up to 30 bu. per acre			30 to 60 bu. per acre			Over 60 bu. per acre	
	Grain and supplement per head per day (pounds)							
Grain (shelled corn equivalent)	2 (Ranging from 1 to 3)			1.5 (Ranging from 1 to 2)			1 (Ranging from 0 to 1)	
35% balanced supplement	1.5 (Ranging from 1 to 2)			1.5 (Ranging from 1 to 2)			1.5 (Ranging from 1 to 2)	
	Per cent protein in total ration when feeding 1.5 pounds 35 per cent balanced supplement with variable amounts of grain							
	(Pounds shelled corn)			(Pounds shelled corn)			(Pounds shelled corn)	
	1	2	3	1	1.5	2	0	1
	(Per cent protein)			(Per cent protein)			(Per cent protein)	
Sows	12.0	13.3	14.4	12.7	13.4	14.0	13.4	14.2
Gilts	13.3	14.8	17.2	14.0	14.9	15.5	14.6	15.6

amount of silage. Gilts will eat 8 to 12 pounds (average 10) and sows 10 to 15 pounds (average 12) of corn silage daily (5). Gilts will eat 5 to 10 pounds (average 7) and sows 7 to 12

TABLE XXXXVII Suggested Supplements Recommended by Iowa Station for Silage Fed to Sows (5)

Pounds per head daily	1.5 (1 to 2)[a]	0.5 (0.5 to 1)[a]	1.0 (0.75 to 1.5)[a]
(Ingredients)	(No. 1) Corn silage supplement[b]	(No. 2) Grass silage Supplement[c]	(No. 3) General silage Supplement[d]
50% meat and bone scraps	500	700	600
44% soybean oil meal	865	800	820
17% dehydrated alfalfa meal	300	—	200
25% dried distillers' solubles	100	—	—
Steamed bonemeal	180	400	300
Iodized salt	40	80	60
Trace mineral premix	15	25	20
Vitamin antibiotic premix			
Vitamin D_2	5 million I.U.	10 million I.U.	8 million I.U.
Riboflavin	9 grams	—	6 grams
Calcium pantothenate	30 grams	—	20 grams
Niacin	50 grams	—	30 grams
Choline chloride	50 grams	—	25 grams
Vitamin B_{12}	60 mg	120 mg	90 mg
Antibiotic(s)	60 grams	120 grams	90 grams
Total pounds	2000	2005	2000

[a] Range of supplement per head daily.

[b] Corn silage needs supplementation primarily with protein, minerals, and B vitamins.

[c] Grass silage needs supplementation mainly with phosphorus and the right kind of protein to balance the amino acids.

[d] Supplements No. 1 and No. 2 are for corn or grass silage. The general silage supplement is suggested when it is desirable to use only one supplement for both corn or grass silage.

2. This is a good way to keep sows from getting too fat. Especially will this be the case with sows from which pigs are weaned early, since these sows will not lose as much weight during lactation.

3. High-quality silage, properly made, is the closest substitute for pasture from a nutritional standpoint.

4. Silage is usually available on farms where beef and dairy cattle are fed. This makes it readily available for swine at a reasonable cost, since it is already being made for the other livestock.

5. It will supply nutritional factors during the winter which might not otherwise be supplied unless the farmer is feeding exceptionally well-balanced rations. Thus, it might help many poorly balanced rations.

6. It makes possible the use of greater amounts of grass and legume forage in swine rations.

Problems involved in feeding silage.

1. Feeding silage alone, without proper supplementation, will result in poor litters.

2. Feeding silage to average or small herds is hard to justify unless it is already available on the farm for use with other livestock.

3. Handling and feeding silage daily is difficult unless adequate equipment and facilities are available.

4. Silage fed to sows should be of high quality so as to be palatable. Silage made from corn nearing maturity, or matured, is unpalatable. Corn silage is palatable when the kernels are dented and most of the leaves are still green when ensiled. The use of corn or molasses as a preservative will increase the palatability of grass or legume silage.

5. Baby pigs may have digestive troubles if they eat silage. This can be prevented hy separating the pigs and sows at feeding time.

6. Moldy silage should never be fed to sows or gilts.

Sows evidently have a large digestive system which has not been utilized to capacity. They will consume quite a large

amount of silage Gilts will eat 8 to 12 pounds (average 10) and sows 10 to 15 pounds (average 12) of corn silage daily (5). Gilts will eat 5 to 10 pounds (average 7) and sows 7 to 12

TABLE XXXXVII Suggested Supplements Recommended by Iowa Station for Silage Fed to Sows (5)

Pounds per head daily	1 5 (1 to 2)[a]	0 5 (0 5 to 1)[a]	1 0 (0 75 to 1 5)[a]
(Ingredients)	(No 1) Corn silage *supplement*[b]	(No 2) Grass silage *Supplement*[c]	(No 3) General silage *Supplement*[d]
50% meat and bone scraps	500	700	600
44% soybean oil meal	865	800	820
17% dehydrated alfalfa meal	300	—	200
25% dried distillers' solubles	100	—	—
Steamed bonemeal	180	400	300
Iodized salt	40	80	60
Trace mineral premix	15	25	20
Vitamin antibiotic premix			
Vitamin D_2	5 million I U	10 million I U	8 million I U
Riboflavin	9 grams	—	6 grams
Calcium pantothenate	30 grams	—	20 grams
Niacin	50 grams	—	30 grams
Choline chloride	50 grams	—	25 grams
Vitamin B_{12}	60 mg	120 mg	90 mg
Antibiotic(s)	60 grams	120 grams	90 grams
Total pounds	2000	2005	2000

[a] Range of supplement per head daily

[b] Corn silage needs supplementation primarily with protein, minerals, and B vitamins

[c] Grass silage needs supplementation mainly with phosphorus and the right kind of protein to balance the amino acids

[d] Supplements No 1 and No 2 are for corn or grass silage The general silage supplement is suggested when it is desirable to use only one supplement for both corn or grass silage

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4. Silage is usually available on farms where beef and dairy cattle are fed. This makes it readily available for swine at a reasonable cost, since it is already being made for the other livestock.

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3. Handling and feeding silage daily is difficult unless adequate equipment and facilities are available.

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5. Baby pigs may have digestive troubles if they eat silage. This can be prevented by separating the pigs and sows at feeding time.

6. Moldy silage should never be fed to sows or gilts.

Sows evidently have a large digestive system which has not been utilized to capacity. They will consume quite a large

sow is on full feed in 7 to 10 days after farrowing After this, the ration may be self-fed or hand-fed It is very important not to force the sow too fast during the first week or 10 days after farrowing Otherwise, she may develop milk fever, her udder may become caked, or scouring may develop in the small pigs because of overeating

While sows are being brought up to full feed, watch their udders and the droppings of the young pigs This will serve as a guide concerning whether they are being brought up on full feed too fast After the danger of overfeeding is past, then the sow should be fed an excellent, well-balanced ration to stimulate good milk production

Tables XXXIX and XXXXV give rations recommended by the Iowa and Illinois stations for feeding sows before and after farrowing Many other bulky rations can be used Wheat bran and oats are good bulky, laxative feeds Use them at levels of 30 to 40 per cent of the ration Some feeders also add about 5 per cent linseed meal as a laxative feed

Some swine producers are trying high levels of antibiotics shortly before and after farrowing (see section 9 3e) They hope this will prevent the infections and complications which sometimes occur during and after farrowing Experimental information is lacking on this practice

9 5 FEEDING DURING LACTATION

The feed requirements of the sow during lactation are considerably greater than during gestation This is because of the increased amount of nutrients which the sow is putting out in the milk as compared to those put into the developing fetuses (see Table XXXVII)

For example, California workers (19) in 1935 summarized the information obtained by various investigators on milk production by sows During an 8-week lactation period the average milk production per sow was 413 2 pounds of milk with a range of 388 2 to 638 4 pounds The amount of milk produced

pounds (average 10) of grass silage per head per day (5). These figures will vary somewhat depending on the size of the animal, the quality and palatability of the silage, and the remainder of the ration given the animal. They can, however, be used as guides as to daily silage consumption.

Tables XXXXVI and XXXXVII give recommendations by the Iowa Station (5) for supplements and level of supplementation for sows fed corn silage or grass silage during pregestation or gestation. These supplements and recommended levels might be modified somewhat as more information is obtained on feeding silage to sows. They can be used, however, as a good guide concerning supplementation of silage for sows.

The Purdue Station (6,7) obtained good results using corn silage or grass silage for sows. The silage-fed sows averaged 0.3 to 1.3 more pigs per litter at 8 weeks than those fed the control ration without silage. Feed costs were also lowered with silage feeding. They also showed that ground corn and minerals alone are not a satisfactory supplement for grass silage for sows. Additional protein and vitamins are also needed. A high-quality mixed-protein supplement including vitamins and minerals is needed to balance the deficiencies of corn silage for sows.

9.4 FEEDING BEFORE AND AFTER FARROWING

The ration fed should be reduced and made more bulky and laxative a few days before farrowing. This will prevent constipation and reduce or prevent a feverish condition in the sow. Wheat bran is a good laxative feed and can be substituted for about half of the regular ration. On the day the sow farrows, she should be given no feed. She should be given plenty of water, however. It should be warmed in cold weather to remove the chill. If the sow appears hungry, she might be given a half pound or so of wheat bran as a slop.

The day after she farrows, the sow can be fed 2 or 3 pounds of a bulky, laxative ration. The ration can be increased in amount gradually and changed to a more concentrated form until the

litter, the condition of the sow, and other factors The vigor, condition, thriftiness, and weight of pigs at weaning will depend largely on their milk supply Thus, it is important that sows be fed adequate rations in sufficient amount to provide all the essential nutrients needed for excellent milk flow

9 5a *Amount to Feed*

It is recommended (see Table II) that a 350-pound gilt be fed 11 pounds of total feed daily, or at the rate of 3 14 per cent of her body weight A 450-pound mature sow would be fed 12 5 pounds of feed or at a rate of 2 78 per cent of her body weight In other words, a level a little above or a little below 3 per cent of body weight seems to be about right for gilts and sows These levels can be used as a guide in feeding sows and gilts It must be emphasized, however, that these levels of feeding will vary depending on the ration used and on the condition of the animals The amounts fed will also vary with the litter size and with the milking ability of the sow The rate should be decreased if the animals get too fat and increased if they get too thin If bulky rations are used, then the level of feeding would be increased

9 5b Weight Changes during Lactation

See section 9 3b for a discussion on weight changes and Table XXXVIII for data on weight losses during lactation These weight losses will vary for various reasons as discussed in section 9 3b Usually the heaviest milking sows are the biggest losers in weight Self fed sows usually lose less than sows which are hand-fed Early weaning will decrease weight losses since the pigs will not be kept with the sows so long The feeding program during lactation should be regulated to keep weight change within reasonable and accepted limits

9 5c Value of Forages and Alfalfa

Both pasture and alfalfa are very valuable in sow rations, as discussed in section 9 3c Pasture is an excellent feed for sows

daily by sows averaged 6.8 pounds with a range of 3.4 to 11.6 pounds daily.

There evidently is considerable variation in the amount of milk produced by sows. This is dependent on the ration fed, the inherent ability to produce milk, the number of pigs in the

Fig. 45. Note difference in condition of two sows during lactation period. The sow on the bottom is being fed an adequate ration, whereas the one on the top is not. (Courtesy T. J. Cunha, Florida Agricultural Experiment Station.)

source of minerals and vitamins Pasture is especially important as a source of vitamins It contains an unidentified factor (probably a vitamin) or factors, which is very important for the lactating sow It also encourages exercise for the sow and reduces the cost of maintaining her Thus, there are many reasons why pasture is important in sow rations

Alfalfa is the closest substitute for pasture and should be used when pasture is not available The Illinois Station (2) showed that a protein supplement was beneficial to sows fed corn and minerals on pasture It reduced death losses, decreased loss of weight during lactation, reduced corn needs, and resulted in heavier pigs at weaning Table XXXX gives recommended rations for sows being fed either on poor pasture or on good pasture which can be used as a guide in making up rations for sows on pasture

9 5d Rations to Use

Tables XXXIX, XXXX, and XXXXI give rations recommended by the Iowa, Illinois, and Michigan Stations These are given as examples of rations for lactating sows and can be used as a guide in making them up Consult your state experiment station for rations recommended in your area

There is still considerable variation in rations recommended to take advantage of using feeds more readily available in various sections of the country Also, there is still much to be learned concerning levels of nutrients and certain feeds and supplements to use in lactating rations for maximum performance Thus, one needs to keep this in mind when comparing rations recommended by various experiment stations A careful study of the feeding value of feeds and nutrient requirements of sows is needed in putting together lactation rations which will give good results

The results obtained during lactation will also be influenced by the ration fed during gestation and even before that Therefore, an excellent ration during lactation may not wholly overcome the carry-over effect of a poor ration fed during gestation or even during the growth period of the gilt This means one

during lactation; this has been shown by many investigators. It decreases the need for protein in the ration and is an excellent

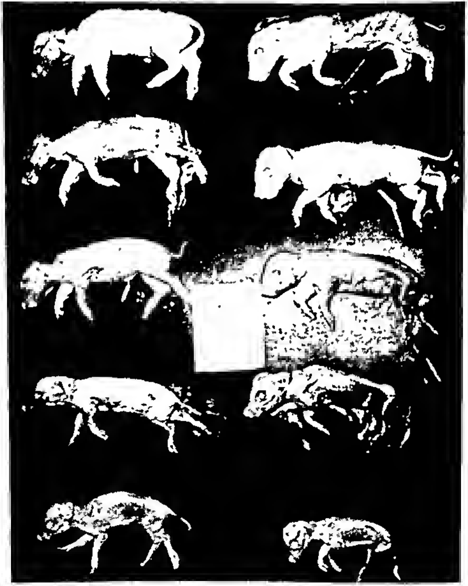

Fig. 46. Note litter from a riboflavin-deficient sow. All pigs were born dead and some were in the process of resorption. Pasture or high-quality alfalfa meal are excellent sources of this vitamin. (Courtesy T. J. Cunha and M. E. Ensminger, Washington Agricultural Experiment Station.)

pigs by one to two per litter, or to a total of approximately eight pigs About the same results, however, were obtained by raising the protein content of the ration to 17 5 or 20 per cent

No harmful effects have been reported from using antibiotics with lactating sows Since some reports have shown antibiotics to benefit reproduction (see section 9 3e) and there is one report on their benefiting lactation (13), the author would recommend their use in lactation rations It is possible they would benefit lactating sows under average farm conditions where the ration is not always well balanced and sanitation is rather poor at times Under these and other stress factor conditions, the antibiotic may be beneficial, whereas it may not always be beneficial under experiment station conditions, where better feeding, sanitation, and management is practiced Table XVIII gives information on the level of antibiotic recommended for sows by eight swine specialists One specialist made no recommendation, two did not recommend antibiotics, and five specialists recommended their use for sows The level recommended averaged 6 1 mg per pound of feed or 12 2 grams per ton of feed The range in antibiotic level varied from 10 to 40 grams per ton of feed Until more information is available, most swine specialists feel that a level of approximately 10 grams of antibiotics per ton of a complete feed is about right to include in lactation rations

9 5g The Feeding Value of Silage

There is virtually no information available on feeding silage to sows during lactation Some swine authorities feel it can be used during lactation, but in smaller amounts than during gestation, since it is bulky and would limit total energy intake of the sow If too much silage was fed, it would restrict total feed intake and thus would limit milk production It might be used in lactation rations as a substitute, or a partial substitute, for pasture or alfalfa meal ordinarily included in the ration

Until experimental information is obtained, there is no definite recommendation which can be made on levels of silage to use in lactating rations for sows Those who wish to try it, however,

needs to evaluate carefully the previous dietary history of the animal when trying to determine how adequate a ration may be for lactation. This also means that there is no period in the life cycle of animals kept in the herd for reproduction when they can be fed inadequate rations. Any break in the cycle—a period of poor feeding—will have its harmful effect later on the ability of the animal to conceive, reproduce, and lactate.

9.5e Self-Feeding vs. Hand-Feeding

See section 9.3f for a previous discussion on this subject. More self-feeding of lactating sows is practiced than with sows during gestation. This is because feed intake needs to be restricted during gestation to keep the sow from becoming too fat. Thus, self-feeding during gestation requires a ration bulky enough to limit energy intake. During lactation, however, even hand-fed sows are virtually on full-feed. They are consuming about twice as much as during gestation, because of their increased feed requirements for milk production.

Thus, the practicality and safety of self-feeding lactating sows is better established than that of pregnant sows. Self-feeding lactating sows is one sure way to have feed available for the sows all the time and thus insure maximum milk production. Sows with small litters, however, should not be self-fed, since the extra feed will not be needed for milk production. These sows should be separated and fed restricted rations in line with the number of pigs suckling them.

Tables XXXIX, XXXX, and XXXXI give examples of lactation rations recommended by the Iowa, Illinois, and Michigan Stations which can be self-fed to sows or gilts.

9.5f The Value of Antibiotics

See sections 6.0b and 9.3e for a previous discussion on this subject. Very little experimental information is available on beneficial effects of antibiotics on lactation. U.S.D.A. studies (13) showed that with a ration containing 15 per cent protein, the use of aureomycin generally increased the number of weaned

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should start with low levels and gradually increase it as much as is possible without reducing milk production adversely. In some cases, it might still be economical to feed a certain amount of silage, even though it may reduce weaning weights to a certain extent.

Silage would certainly have a place in sow rations after they have weaned their pigs. It could serve as a large part of the ration, depending on the weight gains desired with the sows. It could especially serve as a large part of the ration where maintenance, or only small gains, were desired.

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APPENDIX

Swine Management Recommendations*

I 23 Management Recommendations for Swine during Breeding—Gestation for Profitable Production

A General Management

1. Gilts to be retained for the breeding herd should be separated from the market herd at 4 to 5 months of age or at 150 to 175 pounds They should have at least 12 well developed teats
2. Gilts should be at least 8 months old and weigh near 250 pounds before they are bred
3. Worming of sows and gilts before they are bred is recommended, and sanitary measures should be followed to prevent reinfection
4. "Flushing" (increasing feed intake) during the breeding season is recommended The feed intake should be increased 7 to 10 days before breeding starts and maintained until all sows or gilts are bred
5. Under conditions of hand, or individual mating, two services per sow or gilt are recommended The first mating on gilts should be on the first day of estrus and the first mating on sows on the

* Developed by the Nutrition Council of the American Feed Manufacturers Association with cooperation from the nation s Land Grant Colleges Agricultural Experiment Stations and U S Department of Agriculture

14. The use of a breeding crate is recommended when breeding gilts to old boars. It is often desirable to use a breeding crate when mating old sows to young boars.
15. Hand or individual mating of boars to sows or gilts is recommended over field mating. However, if field mating is practiced, two methods are recommended. One method is to split the sow or gilt herd so as to have one boar per group. Another method that is recommended is to alternate boars in the sow or gilt herd; that is, use one boar or set of boars one day and another boar or set of boars the next day.
16. On good legume or legume-grass pasture, allow 10 to 12 gilts or 8 to 10 sows per acre.
17. The square feet of housing or shade per animal should be as follows:

	Winter (housing)	Summer (shade or housing)
Gilt, or junior boar	15 sq ft	17 sq. ft.
Sow, or mature boar	18 sq ft.	20 sq ft.

B. Feeding Management

18. Hand feeding of sows and gilts during gestation is generally recommended as greater utilization of pasture and other desirable roughages can be attained and the condition of the sows and gilts can be more closely watched, but specially adapted bulky rations can be successfully self-fed.
19. When sows and gilts are self-fed during gestation, the number per linear* foot of feeder space, or

* Linear foot = one foot of feeder or watering space. For example, a 6-foot feeder open on both sides has 12 linear feet of feeding space. The same principle applies to trough space.

second day of estrus. The second service should follow the first by 24 hours.

(*Note:* When only one mating can be made during the estrus period, it is recommended that gilts and sows be served on the second day of estrus.)

6. When weaning under two weeks of age, it is recommended that sows be bred on the second heat period after weaning. It is generally satisfactory to breed sows on the first heat period following weaning at three or more weeks.
7. It is recommended that gilts and sows be kept separate during the gestation period, unless they are self-fed a bulky ration.
8. Effective mange and lice treatment is recommended during gestation.
9. Boars should be 8 months old before being used in the breeding herd.
10. Whenever practical, it is recommended that boars be used to serve several sows or gilts outside the breeding herd prior to serving those in the breeding herd.
11. Boars of the same age or size can be run together during the off-breeding season. Boars of different ages, junior and mature, should not be run together.
12. The recommended size of exercise lot for holding a boar is $^1/_4$ acre.
13. The maximum number of services per boar should be:

	Per day	Per week	Per month
Mature boar*	3	12	40
Junior boar*	2	8	25

* Mature boar considered to be 15 months or older, junior boar under 15 months.

mum lengths of 6 feet for gilts and 7 feet for sows The space beneath the bottom board should be $^1/_2$ the stall width The recommended minimum width on each side of the stall or crate for pigs up to 2 weeks is 18 inches

5 Guard rails 8 inches above the bedding and 8 inches from the wall are recommended in central farrowing house pens and individual farrowing houses

6 The farrowing pen or individual farrowing house should be lightly bedded with chopped or short straw or hay, shavings, ground corn cobs, bagasse, peanut hulls, cottonseed hulls, oat hulls, or other suitable bedding material More liberal bedding may be used in unheated houses during cold weather provided it is short or fine material that will not interfere with the movement of the pigs

7 Recommended shade area is 50 square feet per gilt and litter and 60 square feet per sow and litter

B Feeding and Watering Space

8 For self-feeding either in dry lot or on pasture, a minimum of one linear foot of self-feeder space or one self-feeder hole per sow or gilt and litter is recommended provided the young pigs have additional feeding space in a creep

9 For hand-feeding in troughs either in dry lot or on pasture, a minimum of $1^1/_2$ linear feet of feeding space is recommended per sow or gilt and litter provided the young pigs have additional feeding space in a creep

10 For watering by automatic cup, provide at least one cup, not less than 6 inches in diameter or the equivalent, for each 4 sows or gilts and their litters (An automatic waterer with 2 openings should be considered 2 cups) For hand water-

self-feeder hole, should be as follows: Pasture 3 to 4; Drylot 2 to 3.

20. For hand feeding in troughs of gilts and sows during gestation, or for hand watering, the linear feet of space required per gilt or sow is $1\frac{1}{2}$ to 2 feet.
21. When alfalfa hay is fed in a rack, 4 sows may be fed per linear foot of rack space.
22. Bred sows and gilts may be used to glean corn left in fields, provided an excessive amount of corn is not on the ground and supplement is available.
23. One automatic watering cup should be provided for each 12 gilts, or for each 10 sows. (An automatic waterer with 2 openings should be considered 2 cups.) Additional watering space may be required during warm weather.

II 21 Management Recommendations for Sow and Litter

A. Housing and Shelter

1. A farrowing house temperature of 55° to 65° F. is recommended provided adequate ventilation is obtained.
2. Heat lamps placed in a corner, accessible only to pigs, are recommended especially when the farrowing house temperature falls below 65° F. If a heat lamp of 250-watt size is used, it should be suspended approximately 24 inches above the bedding. Condition pigs to doing without the lamp by turning it off during warmer periods or raising it.
3. Farrowing pens in a central farrowing house or individual farrowing houses should have a minimum size of 6 feet by 8 feet for gilts, and 8 feet by 8 feet for sows.
4. Farrowing stalls or crates should have widths of 20 inches for gilts and 24 inches for sows, and mini-

ods This also may be necessary for pigs farrowed on pasture, when weather is unfavorable

15 The age at which litters and sows may be run together should usually be 2 weeks, although small groups may be put together as early as one week The age difference between such litters should not be more than one week in a central farrowing house or 2 weeks on pasture The recommended number of sows with litters put together in a group is not more than 4 in a central farrowing house, or 6 on pasture

16 On good legume or legume-grass pasture, allow 6 to 8 sows or gilts and their litters per acre

17 Castration of the pigs should be done during the first 4 weeks It should not be done during the 3 weeks following cholera vaccination Also, pigs weaned at 4 weeks or earlier should not be castrated within one week of the time of weaning

18 Pigs should be protected from infection by worms as well as other diseases by good sanitation Worming before weaning is not recommended and it should not be done within the 3 weeks after vaccination with living (virulent or modified) hog cholera virus

19 Cholera, erysipelas, and certain other diseases are prone to affect swine in various parts of the country These diseases, where they do arise, can limit other efforts toward efficient pork production Therefore, veterinary medical advice should be sought with regard to proper methods of vaccination and other disease control measures

D Weaning

20 Pigs may be successfully weaned at 5 to 6 weeks without the use of a sow's milk substitute when proper nutrition and management are practiced

ing in troughs, provide at least 2 linear feet of trough space per sow or gilt and litter. Additional watering space may be required during warm weather.

11. Creep feeding beginning the first week is recommended. The maximum number of pigs per linear foot of feeder space should be 5. The edge of the feeder trough should not be more than 4 inches above the ground or floor. A maximum of 40 pigs per creep may be allowed.

    Creep feeders should be placed close to a water supply, and near the area where the sow is most of the time. They should be inside, in a well lighted place in cool weather, and when placed outside in warm weather should be covered to provide shade and protection from rain.

C. General Management

12. When possible, the size of litters should be adjusted to the number of functioning teats or nursing ability of the sow. Transferring pigs from sow to sow should be done as early as possible. Three to 4 days after farrowing is usually the maximum length of time that this can be done, unless the odor of the pigs is masked, when it may be possible to transfer at a later time.
13. For large litters, pigs that are to be transferred, or when injuries to pigs or sows' teats are a problem, clipping needle teeth of pigs at birth or the first day is recommended. Only the tips of these teeth should be clipped.
14. Anemia in pigs farrowed in houses should be prevented beginning the first week by making clean soil or sod available, copperas solution on the sow's udder, individual iron pills, or other meth-

3. Three self-feeder holes, or 3 linear feet of mineral box space, should be allotted for 100 pigs when salt or a mineral mixture is fed free-choice.
4. For hand feeding in troughs, or for hand watering, the length of the trough per pig should be:

Weaning to 75 lbs	.75 ft.
76 lbs to 125 lbs	1 00 ft.
126 lbs to market	1 25 ft.

(A 10-foot trough is considered to provide 10 feet of feeder space whether pigs eat from one or both sides.)

5. When pigs are confined from weaning to market, 15 sq. ft. of feeding floor space should be provided per pig if the pigs are fed from troughs and 10 sq. ft. of feeding floor space if fed from self-feeders. This is in addition to sleeping space.
6. One automatic watering cup should be provided each 20 pigs. (An automatic waterer with 2 openings should be considered 2 cups.)
7. The minimum capacity waterer for 10 pigs per day should be 25 gallons in the summer time and 15 gallons in the winter time.
8. The drinking water should not fall below a temperature of 35 to 40° F during the winter

B. General Management

9. The area of shelter provided should be.

	Summer time (shade or housing)	Winter time (housing)
Weaning to 75 lbs	7 sq ft	6 sq ft
76 lbs. to 125 lbs	9 sq ft	8 sq ft
126 lbs to market	12 sq ft.	10 sq. ft

21. If pigs are to be weaned at 5 weeks or earlier, the following conditions are recommended:

Age in weeks	5	4	3	2	1
Minimum pig wt., lbs.	21	15	12	9	5
Farrowing house temperature, °F.	60	65	70	75	75
Minimum floor space per pig, sq. ft.	6	5	4	4	4
Maximum no. of pigs per linear ft. of feeder space	4	4	4	5	5
Maximum no. of pigs per linear ft. of water space	10	10	12	12	12
Maximum no. of pigs per group	25	20	10	10	10

For early weaned pigs, housing that is warm, dry, and draft free is required. Supplemental heat such as a heat lamp and special feeders and waterers are recommended.

III 15 Management Recommendations for Growing-Fattening Swine

A. Feeding Management

1. The number of pigs per linear foot of self-feeder space or pigs per self-feeder hole should be:

	In dry lot	On pasture
Weaning to 75 lbs	4	4–5
76 lbs. to market	3	3–4

2. The percentage of self-feeder space given to protein supplement should be:

	In dry lot	On pasture
Weaning to 75 lbs.	25%	20–25%
76 lbs. to 125 lbs..	20%	15–20%
126 lbs. to market..	15%	10–15%

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10. The use of sanitary hog wallows during hot weather is recommended. Up to 50 pigs can be accommodated per 100 sq. ft. of wallow provided shade or shelter is near-by.
11. Ringing of pigs is recommended where rooting becomes a problem.
12. A program of strict sanitation to prevent infestation is recommended for control of round worms in swine. Where such a program is not effectively carried out, worming of pigs soon after weaning, and repeated later if needed is recommended.
13. Effective mange and lice treatment is recommended at weaning and whenever needed thereafter.
14. On good legume or legume-grass pasture allow 20 growing-fattening pigs per acre on a full feeding program and 10 to 15 per acre on a limited-feeding program.
15. Pigs of widely varying weights should not be run together. It is recommended that the range in weight should not exceed 20% above or below the average.